ELEMENTS

OF

CHEMISTRY,

THEORETICAL AND PRACTICAL.

BY

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Nec manus nuda, nec intellectus sibi permissus, multum valet ; instrumentis et auxiliis res
perficitur, quibus opus est, non minus ad intellectum, quam ad manum.—BACON.

THIRD EDITION.

JAMES HAY, Esq. M. S. A.

MY DEAR SIR,

It is with great pleasure that I avail myself of the opportunity of dedicating this Work to you, in grateful remembrance of the many obligations you have conferred on me since you called me to give the first Course of Lectures on which I entered, and as a small tribute to those talents, and to that knowledge and love of science, which have enabled you to find leisure, in the midst of numerous professional engagements, to establish Institutions for the advancement of knowledge as well as for the relief of the distressed, the value of which is best evinced by the effects they have produced, and by the lasting memorials with which your fellow-citizens have presented you.

Believe me,

My Dear Sir,

With the most sincere regard and esteem,

Ever faithfully yours,

D. B. REID.

To JAMES HAY, Esq. Links, Leith.

ADVERTISEMENT.

This Edition has been greatly extended, so as to present a full body of Chemical Science, Theoretical and Practical.

It contains the GENERAL PRINCIPLES of CHEMISTRY, including the Atomic Theory—Heat—Light—Electricity —Galvanic Electricity, &c.

The ELEMENTS, and their Compounds, including Organic Chemistry—the Experimental Illustrations of the Lecture-Room, along with the Manipulations of the Practical Class—the Preparation and Application of Tests—the Detection of Poisons and Adulterations.

The LABORATORY.—Ventilation of the Laboratory, Miscellaneous Apparatus, Blowpipe, Tube Apparatus, Flat-Glass Apparatus, &c.

A Short Introduction to Chemical Analysis, with Brief Exercises, illustrative more especially in Qualitative Analysis.

In this Work, while the great object has been to enable the student to become acquainted with the theory and practice of Chemistry, and the most approved Apparatus, the Chapters on the Blowpipe, Tube Apparatus, Flat-Glass Apparatus, &c. will enable those who have not access to the extended arrangements of a well-stored Laboratory, to perform Test Experiments at the most trifling expense, and to examine practically on a small scale, while studying at home, all the most important phenomena of Chemical Science.

PREFACE.

The object of this Work is to explain the principles of Chemistry, and to describe a systematic and extended series of chemical experiments, with precise and minute directions for performing them; so as to afford a proper foundation for acquiring a knowledge of the theory of this science, and habits of practical skill in chemical operations.

Chemistry is now gaining ground every day as a branch of general education, not only from its acknowledged importance to those who are engaged in particular professions, but also from the general progress of the science, and the extent to which it can be applied in explaining the phenomena of nature, and improving the processes of art.

Chemistry is now no longer confined to particular professions, arts, and manufactures, but extends its dominion over the whole economy of nature, and is seen ministering·in every direction to the comforts and necessities of daily·life. Wherever there are animals, vegetables, or minerals,—wherever there is earth, air, or water,—its agencies are found to be in continued operation, and to act an essential part in sustaining the life, order, and harmony of the whole. The

power and number of its instruments, the infinite variety of materials on which it operates, the endless combinations which it can effect, and the creative energies it exerts, have given a splendour to its progress that has arrested the attention of the world, and excited a daily increasing interest in its investigations.

There is perhaps no branch of knowledge more extensively cultivated at the present moment'; and in addition to the daily increasing accumulation of facts in the experimental laboratory, and in the practical operations of science in connection with arts, manufactures, and mines, no preceding period has seen more eminent men devoted to the cultivation of Chemistry, or extending more rapidly its former boundaries by their researches in the philosophy of this science. The new associations also that have appeared of late in almost every civilized country, have facilitated greatly the acquisition of knowledge, while the periodical press diffuses throughout the globe a knowledge of all that is interesting and important in the progress of discovery.

Among those whose numerous communications the advanced student will more particularly study, and who are still engaged in the walks of chemical science, we may enumerate more particularly Dalton, Berzelius, Faraday, Gay-Lussac, Thenard, Mitscherlich, Becquerel, Biot, Arago, Rose, Thomson, Mosander, Ure, Liebig, D'Arcet, Graham, and Pelouze; while it is impossible to open any of the scientific journals, without observing many names which are daily attaining higher eminence, and promise soon to rival the illustrious men to whom we have more particularly referred.

In this volume I have necessarily borrowed much from their labours, and have taken several illustrations, more particularly from Mitscherlich, Faraday, and Liebig, which appear in the text.

Although Chemistry is necessarily becoming every day more and more important, yet perhaps its value as an essential branch of general education has not always been duly estimated. Nor is it surprising, when we look at the rapidity with which it has arisen from a subordinate art, and attained a first rank among the liberal sciences, that it should not have yet unfolded all its capabilities, adjusted its methods, and adapted its processes to the various aspects under which a department so broad and comprehensive may be viewed,—to its power of imparting knowledge, or increasing practical skill. It is only from adverting to these considerations that we can explain why the practice of a science so eminently practical as Chemistry, has not been more generally taught along with the theory ; and, indeed, not many years ago, it was not considered possible that classes could be arranged for this purpose, unless at such an expense as must have precluded the greater number of students from taking advantage of them.

I may be here allowed to observe, that the student who engages, in addition to his attendance at lectures, in a series of chemical experiments, properly conducted, is not only acquiring those practical habits which enable him to apply his knowledge to useful purposes, but is placed in a situation the most favourable that can be conceived, to render it at once accurate, permanent, and effective. The interest he

necessarily feels in the success of a process where he is called
upon to act a part, and the striking nature of the pheno-
mena, quicken his attention to every thing that may influ-
ence the result, and force him to an intimate acquaintance
with the chemical relations of every material with which he
operates. Nor is it of small importance in the laboratory
that the teacher, besides superintending each step of the
process, is always present to explain every peculiar difficulty,
and point out whatever is most interesting. Thus, habits
of mental activity and manual dexterity go hand in hand.
Knowledge acquired in this manner stands on its proper
basis ; it is qualified with all the precision, and impressed
with all the force, of actual experience. Nothing is allowed
to escape the attention of the student ; at each step he is
called upon to bring all his knowledge to some practical
test,—an exercise eminently calculated to strengthen all the
powers of his mind, and to train him to habits of accurate
observation and rigorous induction.

Although no written directions can supply the place of
practical habits, or give that dexterity, readiness, and re-
source, which are to be acquired only by being conversant
with the operations of the laboratory, yet much may be done
to facilitate the student's progress, by minute and definite
directions for performing such a series of experiments as may
enable him to acquire, along with the theory, a knowledge
of the practical relations of the science, and the mode of ope-
rating with different kinds of materials and apparatus. It
is with the hope of being useful in this respect that the pre-
sent work has been written ; and, believing that the prac-

tice of the science must be cultivated to a much greater extent than has hitherto been the case, to enable the professional student to attain that knowledge of its details which he is expected to possess, I shall conclude these observations by requesting his attention to the following memoranda, which may be useful to those who are commencing the study of Chemistry.

The great object of every professional student, of every one who may study Chemistry with some more important object in view than the gratification which it presents to every inquiring mind, should be to obtain such a knowledge of the principles and of the practice of the science, as may enable him to conduct processes and perform experiments, to prepare and apply tests, to undertake any ordinary chemical investigation, and to acquire those habits of resource which will render him independent of the complete arrangements of an extensive laboratory, if he is likely to be called upon to operate in situations where these are not accessible to him.

The science of Chemistry is now so extended, that a thorough knowledge, even of the elements, is not to be attained without a steady and devoted attention, sustained for a considerable period. Six months' attendance at Lectures for an hour a-day, and attendance for three months' at a Practical Class, also for an hour a-day, have formed the usual routine of professional education ; but the time allotted to the practice is much too small for what is expected of the student within that period. He should therefore, wherever time and

circumstances permit, devote as much leisure as he can spare
at home to the application of tests on the small scale, with
flat glass apparatus, should he not be able to have access to
a laboratory for a longer period.   Some public boards indeed,
as the Army Medical Board, insist upon six months' attend-
ance on Practical Chemistry, independent of Lectures ; and,
in general, it may be stated, that those advance most rapidly
and certainly in the study of the science who attend the
Lectures and Practice at the same time, for they mutually
assist in laying such a foundation, that the student can
always renew a course of experimental illustrations on the
small scale at home, while he is led to perform numerous test
experiments in attending to other departments of science,
and these assist him much in retaining the knowledge he
may have already acquired.

In studying for the medical profession, as well as for agri-
culture, arts, and manufactures, a thorough knowledge of
Chemistry assists the beginner in all his subsequent studies.
It has been customary, accordingly, to commence with it;
and, in entering upon this branch of science, it may be im-
portant to recommend the beginner to study carefully the
principles of the science in the first place, and, in particular,
the atomic theory and Berzelian symbols, which are as essen-
tial, in the present state of the science, as figures in arith-
metic.   Frequent practice alone can render its details fami-
liar ; and, as the varied facts are apt to escape the memory
unless there be frequent recapitulation, the professional stu-
dent should not omit joining in any examinations, or mu-

tual instruction classes, connected with the course he may be attending.

Nothing tends more, however, to assure the student of his progress than the application of tests, and the writing of symbols, and his success in any simple analytical investigation which he may be called upon to attend to from time to time as an exercise. By practice, and also by drawing up illustrative diagramatic figures, in the manner explained in page 617, and by frequent use of the chemical abacus described in the appendix, he will soon become intimately acquainted with the atomic composition and chemical relation of the more important combinations, which will guide him in tracing the various changes of which they are susceptible.

Again, where the student has not access to the lecture room or to the laboratory, he cannot be too cautious in operating with different materials, the precise nature of which may be unknown to him. Many young experimenters have sometimes injured themselves permanently from this cause. He should also recollect, that there are numerous experiments and processes which may be performed with much less costly apparatus and materials than are employed in the well-stored laboratory; and there is no science where so many experiments can be performed at the most trifling expense, and where a little ingenuity will so often enable the experimenter to obtain the object he may require, though deprived of the apparatus he would have preferred if he were allowed a choice. Every one, indeed, professing to study Chemistry as a science, should at least provide himself with fifty or sixty chemicals, including a few bottles with acids

and alkalis, such as he may obtain in the small museum
fitted up by Mr Macfarlane, with which, if he operate on a
minute scale, he may perform thousands of test experiments.*

It is important also to remember, that, in attending to
the brief introduction to Chemical Analysis, the strength of
acid and alkaline solutions should particularly engage atten-
tion, as these are the principal materials that are employed in a
wide range of chemical operations, and no one can expect to
operate with any degree of facility or precision, who is unable
to estimate the strength of the most important agents which
he may have occasion to employ. He should then endeavour
practically to go through the lessons recommended in Chapter
IV. Part IV., making up parcels containing specimens of the
different substances mentioned in the key, and requesting
any friend to give him one from time to time without telling
him what it is, that he may enter upon the analysis in the
same manner as he may have to operate afterwards when
called upon to undertake any analytical investigation.

See also the list of Chemicals given in page 774.

Symb.		Equiv.	Discovered by	Year.	Symb.		Equiv.	Discovered by	Year.
H.	Hydrogen	1	Cavendish,	1766	Zr.	Zirconium	34.67	Berzelius,	1824
C.	Carbon	6.12	Known to the Ancients.		As.	Arsenic	37.7	Brandt,	1733
O or.	Oxygen	8	{ Priestley,	1774	K.	Potassium	39.2	Davy,	1807
			Scheele,	1775	Sr.	Strontium	43.8	Davy,	1807
B.	Boron	11	Davy,	1807	Ce.	Cerium	46	{ Hisinger,	1804
N.	Nitrogen	14.2	Rutherford,	1772				Berzelius, }	
P.	Phosphorus	15.7	Brandt,	1669	Mo.	Molybdenum	17.9	Hielm,	1782
S.	Sulphur	16.1	Known to the Ancients.		R.	Rhodium	52.2	Wollaston,	1803
F.	Fluorine	18.7	Dr Faraday,	1834	Pd.	Palladium	53.35	Wollaston,	1803
Cl.	Chlorine	35.5	Scheele,	1774	Cd.	Cadmium	55.8	Stromeyer,	1818
Se.	Selenium	40	Berzelius,	1818	Sn.	Tin	58.9	Known to the Ancients.	
Br.	Bromine	78.4	Balard,	1827	Th.	Thorinum	59.6	Berzelius,	1828
I.	Iodine	126.5	Courtois,	1811	Te.	Tellurium	64.2	Muller,	1782
L.	Lithium	10	Arfwedson,	1818	Sb.	Antimony	64.6	Basil Valentine,	1490
Mg.	Magnesium	12.7	Bussy,	1829	V.	Vanadium	68.5	Sefstrom,	1830
Al.	Aluminum	13.7	Wohler,	1828	Ba.	Barium	68.6	Davy,	1807
Ca.	Calcium	20.5	Davy,	1807	Bi.	Bismuth	71.5	Known to Agricola,	1530
Si.	Silicum	22	Berzelius,	1824	W.	Tungsten	94.8	D'Elhuyart,	1781
Na.	Sodium	23.5	Davy,	1807	Ir.	Iridium	98.8	{ Descotils,	1803
Ti.	Titanium	23.5	Gregor,	1791				Tennant, }	
G.	Gluchium	26.5	Wohler,	1828	Pt.	Platinum	98.81	Wood,	1741
Mn.	Manganese	27.7	Gahn and Scheele,	1774	Os.	Osmium	99.7	Tennant,	1803
Fe.	Iron	28	Known to the Ancients.		Pb.	Lead	103.7	Known to the Ancients.	
Cr.	Chromium	28.19	Vauquelin,	1797	Ag.	Silver	196.3	Known to the Ancients.	
Co.	Cobalt	29.5	Brandt,	1773	Ta.	Columbium	184.8	Hatchett,	1802
Ni.	Nickel	29.5	Cronstedt,	1751	Au.	Gold	200	Known to the Ancients.	
Cu.	Copper	31.7 ?	Known to the Ancients.		Hg.	Mercury,	203	Known to the Ancients.	
Y.	Ittrium	32.25	Wohler,	1828	U.	Uranium	217.2	Klaproth,	1789
Z.	Zinc	32.3	Known to Agricola,	1520					

EARTHS discovered before Davy's discovery of the Composition of the Fixed Alkalis and Earths, and not known to the Ancients.

Baryta,	by	Scheele,	1774	Glucina,	by	Vauquelin,	1797
Strontia,		Hope,	1792	Thorina,		Berzelius,	1828
Zirconia,		Klaproth,	1789	Yttria,		Gadolin,	1794

1. Each dot or O (.) prefixed to a symbol indicates one equivalent of oxygen.

2. Compounds are represented by the symbols of their elements. SFe = sulphuret of iron.

3. A figure prefixed to any symbol or symbols, multiplies all that follow, unless a new sign intervene. Thus, $2 \cdot H \dot{:} S = 2 \cdot H + 2 \dot{:} S$.

$2 \cdot H \dot{:} S + \dot{\cdot} K = 2 \cdot H + 2 \dot{:} S + \dot{\cdot} K.$

4. A small figure placed after any symbol indicates that it is to be multiplied,—and does not refer to any other symbol. Thus—$H^2C = 2H + C.$

$G^2N = 2C + N. \quad NH^3 = N + 3H. \quad OC^2H^3 = O + 2C + 3H.$

5. Brackets are often used in representing complicated combinations. $(2HC^2N + C^2NFe) + 2 \cdot K$ = Ferroprussic acid + 2 Potassa.

6. A figure prefixed to brackets inclosing symbols, multiplies them all, whether signs intervene or not, within the brackets.

7. In the Symbolic and Diagrammatic Illustrations, " & " is used to signify a substance added to or separated from another, but + is placed between substances chemically combined. Thus $\dot{:}S\&K$ signifies that sulphuric acid ($\dot{:}S$) is to be added to the potassa ($\cdot K$); but $\dot{:}S + \cdot K$ means sulphate of potassa, or sulphuric acid already combined with potassa.

8. Many vegetable acids and other substances are represented at present most conveniently by *Italic* Capitals, which are used as provisional symbols, adding some succeeding letter where more than one have the same initial letter.

A. Acetic	*Cz.* Carbazotic	*F.* Formic	*M* Malic	*R.* Racemic
B. Benzoic	*Ct.* Citric	*G.* Gallic	*Mc.* Meconic	*S.* Succinic
C. Camphoric	*Cy.* Cyanic	*K.* Kinic	*P.* Prussic	*T.* Tartaric

ABBREVIATIONS.

Temp.........temperature. Fahrenheit's thermometer is always referred to, if no other be particularly mentioned.

Bar......... ..barometer.

☐ ....one measure or volume; the square representing cubic capacity.

⌐ ....half a measure or volume.

Parts. ...... always signify parts by weight, where it is not otherwise stated.

W ....weight.

V . ...volume, or measured bulk.

+ .... .is translated " combined with."

& or and....signifies to be added to, or mixed with.

× ....multiplied by.

= .. ..equal to, composed of, or may be resolved into.

c. i. ....cubic inches.

gr........ ....grain.

sp. gr. .....specific gravity.

Par. . . ...paragraph.

Symb. .. ...symbol.

Synon......synonymes.

Eq. ....equivalent.

The student is recommended to write frequently Symbols and Diagrams, illustrative of the most important cases of chemical action, after he has become familiar with the preceding Table.

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ELEMENTS OF CHEMISTRY

ERRATA.

Page   8, line   2, *for* b *read* d
...   11, ... 30, *for* quotient' *read* product
...   42, ...   3 from bottom, *for* H^2O *read* O^2H
...   54, ...   1 of diagram, 32.2 *read* 30.2
...   76, .. 12 from top, *for* f *read* h
...   121, ... 19, *for* 71.7 *read* 71.4
...   . *for* 31.7 *read* 31.4
...   211, ... 12, *for* silica *read* silicum
...   287, ...   4, *for* in *read* by
..   292, ... 29, *for* OF or ·F *read* OFe or ·Fe
...   293, ... 11, *for* O^3F^2 or ⁝F *read* O^3Fe^2 or ⁝Fe^2
...   389, ... 26, *for* 4.6 *read* 46
...   404, ... 31, *for* 2.03 *read* 203
...   412, ..   7, *for* vapoury *read* vapour
...   457, ... 12, *for* χνανοσ *read* κνανοσ
...   571, ... 16, *for* " after of air" *insert* per minute
...   582, ... 22 from top, *for* 8. *read* 9.
...   625, ... 17, *dele* 2366
...   645, ...   1, *for* OC^2H ⁝21.24 *read* OC^2H ' .23,24
...   . 12, *for* Z_4 nthic Acid 2(SC), &c. *read* Xanthic Acid 2(S:C), &c.
...   656, ... 28, *dele* 2046
...   666, Fig. 266 reversed.
...   688, line 34, *for* by b and c to D *read* by a dd c to d
...   . 37, *for* F *read* f
...   725, ... 17, *for* o *read* c
...   726, ...   1, *for* o *read* c
...   783, ... 32, *for* analytical *read* in analytical
...   797, ...   2 from bottom, *for* d *read* b
...   798, ...   8 from top, *for* IX. *read* II.
...   860, *for* Fig. 40 *read* 589
..   871, line 7 from bottom, *for* 472 *read* 47.2
...   884, ... 23 from top, *for* XLIX. *read* XLVIII.
...   885, ... 17 from top, *for* VI. *read* V.
...   891, ...   3 from top, *for* 135° *read* 185°
...   898, ...   6 from bottom, *for* of inch *read* inch

PRACTICAL CHEMISTRY.

PART I.

DIVISION I.
SIMPLE SUBSTANCES.

CLASS I

SIMPLE SUBSTANCES NOT METALLIC, AND THEIR
COMBINATIONS WITH EACH OTHER.

CHAP. I.—OXYGEN.

Symb. O *or a dot* (.); *Eq. by* W. 8 ; *by volume,* ⌐ (*half
sure. Specific gravity,* 1.026 (*Temp.* 60° *and Bar.* 30) ; W. *of*
100 *c. i.* 34.19 *grs.*
Oxygen evolves light and heat when suddenly compressed. 100 *c. i.
of water, absorb* 3.7 *of oxygen.*

1. OXYGEN is an element that is widely distributed over the
material world, forming about a fifth part of atmospheric air,
eight-ninths of the water of the globe, and existing in large
quantity in most earthy substances. and in the products of the
vegetable and animal kingdoms.   It is procured with facility
from a number of its compounds by exposing them to heat,
when it assumes the form of a transparent and colourless gas,
pre-eminently distinguished by its power of supporting com-
bustion and respiration.   It can unite with all the elements,
and with many of them in several different proportions.   When

A

it combines with the non-metallic bodies, the resulting compounds have usually acid properties; with the different classes of metals it forms alkalis, earths, and the common metallic oxides.

2. PREPARATION.—The substances from which oxygen gas is commonly prepared are the binoxide of manganese, the binoxide of mercury, and the nitrate and chlorate of potassa. The last of these yields the purest oxygen gas, but the first is commonly employed, as it is procured at a moderate price, and affords oxygen sufficiently pure for the purposes to which it is generally applied.

From the Binoxide of Manganese, called also Black Oxide of Manganese, Peroxide of Manganese, or simply Manganese.

3. Oxygen gas may be prepared from the binoxide of manganese by mixing it with rather more than its own weight of aqueous sulphuric acid, and exposing it to the heat of a good lamp or chauffer; 43.7 of the binoxide of manganese, and 49.1 of aqueous sulphuric acid are the more exact proportions. If a larger quantity of sulphuric acid be employed, as one and a half or twice as much, and the heat not continued till a dry mass is obtained, the residuum is removed easily from the retort when the process is finished.

Fig. 1.   4. For this purpose, a tubulated retort is filled about a third full of sulphuric acid, pouring it carefully through a glass funnel, Fig. 1; the manganese in fine powder is then poured through another funnel, previously warmed to render it perfectly dry, shaking the acid from time to time before the whole of the manganese is introduced, that it may not gather into lumps. Should the manganese be put in first, it is not so easily mixed afterwards with the acid, and if it should lie dry on any part of the bottom of the retort, which often is the case when they are introduced in this order, even after they have been well shaken together, the retort is extremely apt to be broken. These remarks apply to all cases where a powder and a liquid are exposed to heat in a glass vessel, whatever form it may have, and the more heavy and insoluble the powder is, the greater is the necessity of attending to them.

5. The retort is to be placed on a ring supported by a brass

Fig. 2.
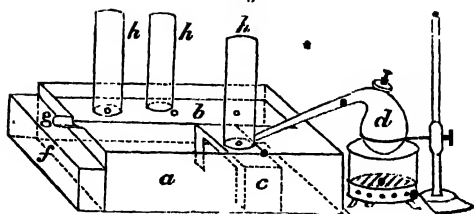
or iron stand, Fig. 2, and fixed in its place by turning a screw when its height has been properly adjusted. If the retort be large, and the ring at a considerable distance from the stem of the retort-stand, weights must be put upon it to keep it steady. The most convenient for this purpose are cylindrical pieces of lead, from half an inch to an inch and a half thick, having the same diameter as the bottom of the retort-stand over which they are placed, a piece of lead being cut out from the centre to the circumference, so as to allow them to be put on or taken off without interfering with any other part of the apparatus.

6. The beak of the retort is introduced below the top of the small stool. This is made of wood, and has lead run into holes bored through it to prevent it from floating in the water of the pneumatic trough. The upper part is hollowed out to collect all the gas that is disengaged, which passes through an aperture in the centre to the pneumatic jar placed immediately above it. The stool is placed exactly on a level with the shelf in the pneumatic trough, and may be taken out, or moved up and down in either direction, as may be required.

7. These troughs are made of wood, copper, or tinned iron, the first kind being oil-painted, and the latter japanned. They may be of any shape or size, and when not accompanied with a stool, the shelf is excavated to allow gas to be more easily collected. The one I have found most convenient is made of wood, and bound together at the corners by plates of brass. It is 24 inches long, 12 broad, and 8 inches deep. The shelf is as long as the trough, and fixed to one of the sides about 1¾ inch from the top; its breadth is 4½ inches; the stool, the top of which is on a level with the shelf, is 7 inches long, and 4½ broad; a small spout is fixed at the upper part of one of the ends of the trough, to convey away any excess of water when the trough becomes too full from the gas displacing the water in the pneumatic jars.

8. *h h h* are jars filled with water, in which the gas may be

collected as it rises through the aperture in the stool ; when
full they may be placed on the shelf till required, or

Fig. 3.

removed on a japanned tin tray, Fig. 3, or small plate.
This is done by merely placing the tray below the
jar under water, and removing it with the small quantity of
water it may contain, which prevents the escape of the gas. The
pneumatic jars required for collecting the gases are made of
different sizes ; where a small quantity of materials is employed,
they may be from 8 inches in length and $2\frac{1}{2}$ in diameter, to 4
inches in length and $1\frac{1}{4}$ in diameter.

9. Before proceeding farther, the student should make him-
self familiar with the method of transferring gases from one jar to
another, operating frequently for this purpose with atmospheric
air. Holding one jar a inverted perpendicularly in the pneu-

Fig. 4.

matic trough and full of water, he
should depress another b full of air
in the water, perpendicularly at first,
so that no air may escape, and in-
cline it afterwards, so as to allow the
air to pass slowly into the other, the
back of the hand holding the jar con-
taining the gas to be transferred being
towards the other jar.
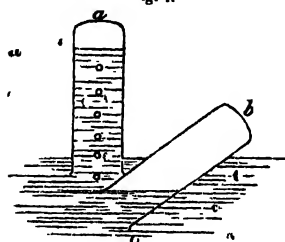
10. The retort is then to be heated by placing a chauffer
below it filled with red hot cinders, free from any smoking
pieces of coal ; they burn better if mixed with a few pieces of
charcoal, and afford a more equal and powerful heat than the
less diffusive flame of a lamp. The small chauffers, as they
are usually made, are seldom properly constructed. The grating
ought to consist of stout pieces of iron-wire, of a suitable
thickness, rivetted to an iron-ring supported on feet, and not of
a thin and flat piece of sheet-iron with a few holes cut in the
centre, as is generally the case, much too small to supply a suffi-
cient quantity of air. A space of about 1 inch at least, should
intervene between the grating and the bottom of the chauffer,
that the fuel may burn freely. The chauffer which I find most
convenient for general purposes is $6\frac{1}{2}$ inches deep, and 6 in dia-
meter ; the grating is fixed $1\frac{1}{4}$ inch above the bottom, which
is supported about the same distance from the ground by feet
rivetted to it.

11. A chimney is of great use in kindling a chauffer quickly, and in raising a higher temperature than the chauffer would otherwise afford ; for a chauffer of the size just described, it may be from 2¼ to 3 or 4 feet long, and the pipe about 3 inches in diameter. Fig. 5. shews the chauffer with the chimney on it. Chauffers have usually wooden handles, which often prove very inconvenient ; they are much better without them; and with a pair of

Fig. 5.
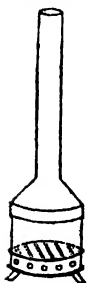
Fig. 6.　　Fig. 7.　　Fig. 8.

strong iron pincers, Fig. 6, they may be moved as conveniently from place to place as when they are provided with a handle. A pair of tinned pincers of iron, Fig. 7, is required for adjusting the fire ; and a long iron rod, bent at the end, for filling the chauffer with cinders from the fire. Black lead crucibles are often converted into chauffers, Fig. 8, by boring holes through them with a file, and putting in a grating made of wire ; and earthen-ware vessels are frequently made for this purpose alone. All of them are easily broken, however, and the beginner will almost invariably find well made chauffers of sheet-iron much more useful. A bright tin-plate must be placed between the chauffer and the table to protect it from the heat, and another between the trough and the chauffer for the same purpose ; a rough tin-plate that has lost all its lustre will not do, as it absorbs instead of reflecting all the rays of heat that fall upon it

12. The gas disengaged by the action of sulphuric acid on the binoxide of manganese must be examined at the commencement of the process, collecting a little for this purpose from time to time in small glass jars inverted and full of water on the shelf of the pneumatic trough. The thumb is placed on the mouth of one of these jars (which need not be above an inch or two long) when full, and a small wax-taper, suspended by a wire (Fig. 9), or a splinter of wood, is introduced after the flame has been blown out, but while the wick is still red If it be immediately extinguished, this arises

Fig. 9.

from the presence of carbonic acid ; but if it burn brighter, and
Fig. 10. is rekindled into a flame, then the oxygen may be col-
lected ; for though it may still be mixed with a little car-
bonic acid, it will be found sufficiently pure for ordinary
purposes.   Fig. 10. represents a convenient mode of sus-
pending a piece of cotton wick, previously dipped in
melted tallow, such as is much used in experiments illus-
trative of the general properties of oxygen.   Iron, cop-
per, or brass wire, may be used for this purpose.

13. The binoxide is often mixed with carbonate of lime ; part
of the sulphuric acid then unites with the lime, and thus car-
bonic acid is at first disengaged.   To prevent this, it is ad-
visable to wash the manganese after it has been reduced to
powder with one part of hydrochloric acid diluted with eighteen
of water.   The acid combines with the lime and forms hydro-
chlorate of lime, which is removed by mixing it two or three
times with water in a jar, decanting it after the powder shall
have subsided.   The carbonic acid is disengaged with efferves-
cence.   It is then dried by spreading it out on a plate and ex-
posing it to the air, or to a gentle heat before the fire.

14. Retorts made of the light green bottle-glass, or of any
other glass free from lead, are the best for this process, as they
are not so apt to be softened by the temperature necessary for
the expulsion of the oxygen as those made of flint-glass ; the
large quantity of the oxide of lead which the latter contains
renders it much more fusible than any of the other kinds of
glass.   In conducting this process, care must be taken to keep
the fire as steady and equal as possible.   The tubulated retort
must be taken from the pneumatic trough when no more gas is
disengaged, to prevent the water from passing back into it, or
the stopple may be removed, which will have the same effect.
If the retort has been exposed to a high temperature, and the
mass inside appear quite hard and solid, the chauffer must not
be suddenly withdrawn, as the cold air playing upon the exter-
nal surface of the glass, while the internal surface is kept hot
by the heated matter within, is very liable to break it.

15. When the retort is cold, water is poured in, and it is
allowed to stand for some hours before the residuum is washed
out, and, in this manner, by repeated washings the dense mass
is at last removed.

16 When a large quantity of oxygen gas is required, it is usually prepared from the binoxide of manganese by exposing it to a red heat in an iron-bottle, placed in a furnace or open fire. The most convenient method of conducting the process, is
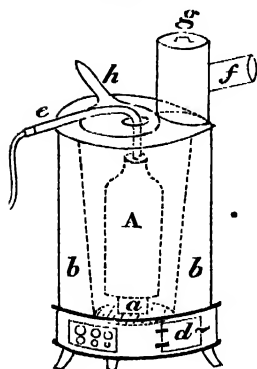
to connect with a bottle (A) containing the manganese, as represented in Fig. 11., a bent tube e, made of a gun-barrel or gas-pipe, and previously accurately fitted to the neck of the bottle by grinding. It is then put into the furnace, so that it shall rest upon a piece of brick or stone a, placed immediately above the grate, and from one to two inches thick. The connection between the iron-bottle and the bent tube is made perfectly air-tight by drawing the finger round the end of it with a little clay before it is introduced, and giving it a slight blow afterwards with a hammer. When the apparatus is properly adjusted, the furnace is filled with red hot cinders till they reach the neck of the bottle, and the cover put on, consisting of a flattened cylinder of baked fire-clay, bound round with an iron-hoop, and with an opening at one of the sides for the passage of the iron-tube. The door (d) of the ash-pit is at the same time opened, that the air may enter freely.

17. The manganese must not be reduced to powder, as it is then very apt to be thrown from the iron-bottle into the bent tube, but merely broken into pieces of such a size as may allow it to be easily introduced.

The gun-barrel (e) is kept cool by wrapping round it a
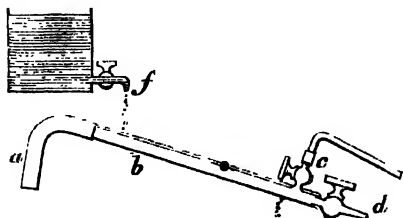
piece of wet cloth, on which a little water is poured whenever it begins to be dry. In Fig. 12 it is represented on a larger scale, b is the cover of thin cotton cloth, leading the water from the cistern f, which drops off at e, and keeps it cool;

c is the stopcock by which the gas is conveyed to the gas-holder, and *b* another stopcock, opened occasionally to allow any water to escape that may condense within the barrel.

18 The furnace represented in the above figure was invented by Dr Black, and is extremely well adapted for a great variety of chemical operations. It consists of a case of strong sheet-iron lined with some very refractory clay (*bb*), the luting increasing gradually in thickness from the top of the furnace to the roof of the ash-pit. The grate is fixed to the iron-plate, which supports the lute, and forms the top of the ash-pit, which has a door for the free admission of air, and a series of apertures with iron plugs to regulate the quantity of air admitted when the door is shut, and a steady and determinate heat required. The smoke is carried away by the pipe *f*, and may be conveyed to any distance by connecting several other pipes of the same kind with it. The last piece may be fixed into an opening in the wall communicating with the vent, or made to pass a few feet up the chimney over the common fire, if the usual conveniences of a laboratory cannot be procured. When more fuel is required, it may be introduced after removing the lid *g*, at the top of the furnace, without displacing any part of the apparatus. Figs. 13. and 14. represent the form of the poker and shovel constantly required in using a furnace of this construction.

Figs.
13. 14.
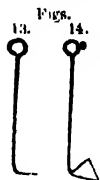
19. The quality of the gas must be ascertained from time to time at the commencement of the process, by attaching a flexible leaden or tin tube to the bent iron-tube, connected with the bottle, as is seen in Fig. 11. The gas issuing from it is collected in a small glass-jar full of water, inverted in a basin or pneumatic trough, also filled with water, and examined in the manner described in 12, page 5.

20. The first portions of gas that are disengaged must be rejected, consisting principally of atmospheric air and carbonic acid, the latter arising from the decomposition of some carbonate of lime, with which the binoxide of manganese is frequently contaminated, and which parts with its carbonic acid on exposure to heat.

The quantity of carbonic acid disengaged varies according to the quality of manganese. The binoxide is seldom in such a

state of purity as to afford nothing but oxygen gas from the commencement of the process.

Occasionally I have seen an inflammable gas disengaged at the commencement of the process, probably from the presence of some woody fibre, as it had a great resemblance to the gas that arises from wood, when it is exposed to heat in close vessels.

21. To collect the gas, large vessels capable of containing several cubic feet of gas, and termed gasholders, are usually employed These vessels are made of sheet copper, japanned both externally and internally, or some-
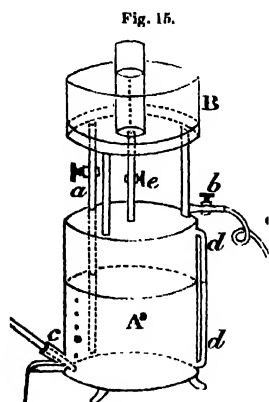
Fig. 15.

times the bottom alone is made of copper, and the sides and top of tin. The annexed figure represents Mr Pepys' gasholder, the most convenient form of this apparatus hitherto contrived. A is the body of the gasholder, intended to contain the gas; B a trough supported on three pillars, resting on A; c a flexible tube conveying gas through an aperture that permits the water to escape as it enters; b a stopcock connected with a flexible tube, through which the gas may be propelled after it has been collected; e another stopcock connected with a tube open at both ends, and passing between A and B, through which the gas may be made to pass when b is shut into a jar full of water placed in the trough B. A tube (a) open at both ends passes through one of the pillars supporting B, and is continued to the bottom of A; d d is a glass-tube open at both ends, and cemented into the upper and lower part of A, to indicate the quantity of gas collected, the fluid in the tube being always at the same level with the fluid in A. When the gasholder is to be used, the aperture at c is closed by a plug made to screw upon it, and water being poured into B, it passes down through a into the body of the gasholder, the atmospheric air being forced through b (which is also opened) as the water rises in A. All the stopcocks are shut when the gasholder is full of water, and the plug which closes the aperture at c being unscrewed, the tube which conveys the gas may be introduced, which will rise through the water as represented in the figure, while the

latter.flows out in a continued stream as long as any gas enters. Great care must be taken not to open any of the stop-cocks while the plug at *c* is unscrewed, as the water would then be forced out with great violence by the pressure of the atmosphere, and the gasholder filled with atmospheric air in a few seconds. When the gasholder is full, the tube *c* is withdrawn, and the plug screwed on; the trough B is then filled with water, and on opening the stop-cock in the tube, *a*, the water descends and presses upon the gas; but none escapes, unless the stop-cocks at *b* or *e* are opened, through either of which it may be propelled by opening the one and shutting the other.

22. Instead of a flexible leaden or tin tube, the gas is frequently conveyed from the gun-barrel to the gasometer by two pieces of brass-tube, joined together by a moveable circular joint, as is seen in Fig. 16.

Fig. 16.
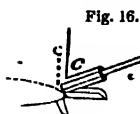
23. The heat of the furnace is regulated by the quantity of air admitted through the plug-holes. When the door is shut, the tube connected with the bottle must not be left in the water after the gas has ceased to come, or when the fire is allowed to decline, otherwise water would be forced through it into the iron-bottle by the pressure of the atmosphere, the heated gas still remaining there diminishing in volume as it cools.

24. Such is the most convenient method of preparing and collecting a large quantity of this gas, when a suitable apparatus can be obtained. On a smaller scale, a bottle made of malleable iron, capable of containing 2 or 3 ounces of the binoxide of manganese, may be employed, a small bent iron-tube, about 18 or 21 inches long, being accurately ground to it and luted as described in 16. The accompanying figure represents this apparatus, the iron-tube being put through an aperture in the chimney of a chauffer, which is then placed upon the chauffer, and a mixture of coke and charcoal already kindled introduced by the top of the chimney. Should a bottle somewhat larger be preferred, it may be heated by a furnace with an aperture at the side, sufficiently wide to allow it to be easily introduced, or in the open fire,

Fig. 17.
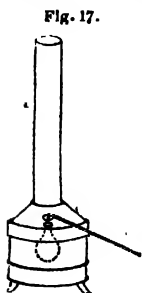
by placing it so as to be exposed to a red heat. The extremity of the tube may be made to dip under the shelf of the pneumatic trough, without any intervening leaden tube. The gas may be collected in glass-jars, or preserved for use in common green glass-bottles with ground stopples, which are to be well dried, and the finger drawn round them with a little gas-lute, before they are introduced.

25. To understand the theory of the preparation of oxygen gas from this substance, the composition of three oxides of manganese must be kept in view, and the following is perhaps the most probable view of their atomic constitution :—

Oxide   = Manganese 27.7 + 8 Oxygen = 35.7 = . Mn
Binoxide = Manganese 27.7 + 16 Oxygen = 43.7 = : Mn
Terdinoxide = Oxide   35.7 + 43.7 Binoxide = 79.4 = : Mn²
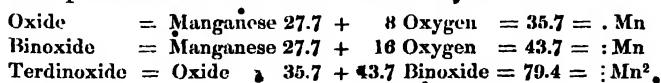
When the oxygen gas is prepared from the binoxide by exposing it to a red heat, every 87.4 parts (two equivalents) give 8 parts of oxygen and 79.4 parts of the terdinoxide remain, the decomposition taking place which is expressed in the diagram.

Fig. 18.

Before decomposition.   *After decomposition.*
:Mn = 43.7 Binoxide, { Oxygen   8 ....8 Oxygen = O
                     { Oxide   35.7
:Mn = 43.7 Binoxide, ... 43.7 ....79.4 Terdinoxide = : Mn²
                Symb. 2 : Mn = O &. : Mn
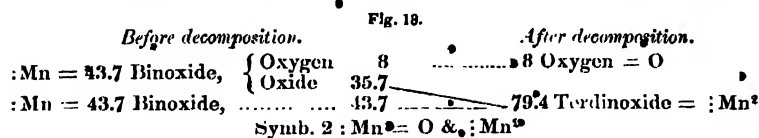
26. As every cubic inch of oxygen gas at a mean temperature and pressure weighs one-third of a grain within a very trifling fraction, and as every 87.4 parts of the binoxide of manganese by weight yield 8 of oxygen at a red heat, or every 11 grains give 1 grain, we have only to multiply by 3 the weight of the oxygen expressed in grains which any quantity of the binoxide can afford (1-11th of its own weight), and the quotient gives the number of cubic inches which it will occupy in the gaseous state.

27. Again, 49.1 parts of aqueous sulphuric acid contain 40.1 of dry acid, and when mixed with the binoxide of manganese, every 43.7 parts give 8 parts of oxygen, sulphate of manganese being left in the retort in the proportion represented in the following diagram :—

Fig. 19.

Before decomposition.   *After decomposition.*
: Mn = 43.7 Binoxide, { Oxygen   8................   8 Oxygen = O
                      { Oxide   35.7   { 75.8 Sulphate of Man-
: S = 40.1 Sulphuric Acid, ... 40.1   { ganese = : S ·Mn
                Symb. : S & : Mn ·= O & : S ·Mn
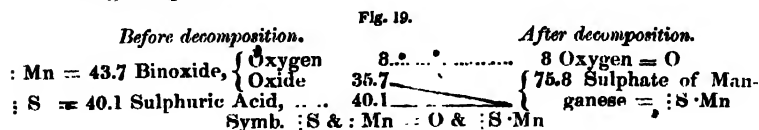
28. Oxygen gas may be procured with great facility from the *binoxide of mercury*, every 219 parts consisting of 203 of mercury (one equivalent), and 16 (two equivalents) of oxygen. In this case the whole of the oxygen is expelled on exposing the oxide to heat; and as the mercury is at the same time volatilized, no part of the apparatus should be made of brass, copper, lead, or of any other metallic substance which might be acted on by this metal.

29. The binoxide is heated in a small green glass-retort by a good chauffer or powerful lamp, the beak of the retort being placed below the shelf of the pneumatic trough; a retort made of flint-glass is generally softened by the heat necessary for the expulsion of the oxygen, and cannot therefore be used. Occasionally an iron retort is employed, Fig. 17, page 10, or the body of the retort may be made of a piece of a gun-barrel. A glass tube is sometimes fixed to the end of the iron tube, in order that we may perceive if the water should begin to go back into the retort after the process has been carried on for some time, when it must be immediately withdrawn. The

Fig. 20.
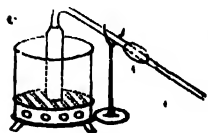
form of this apparatus is represented in the annexed figure, the heat being applied by a chauffer into which red hot cinders and charcoal are put, after the retort has been properly adjusted.

30. If a considerable quantity of the binoxide of mercury has been used, the mercury that is distilled over ought to be kept, as it is extremely pure.

31. Should it be required to shew the deep colour it assumes before it is decomposed, and collect the mercury volatilized during its decomposition, an apparatus similar to the annexed will

Fig. 21.
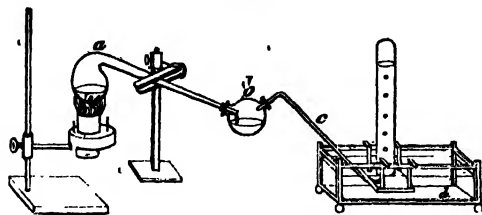
be found convenient. The mixture is put into the retort *a*, the mercury is obtained in the receiver *b*, and the oxygen is collected in the usual manner. This figure shews the usual construction of the plate glass pneumatic trough, the plate of glass being cemented into a strong brass

frame. Instead of a stool, a moveable shelf is suspended from the sides.*

32. The *nitrate of potassa* is another substance that is frequently employed for the preparation of oxygen, when it is not wanted particularly pure. It may be exposed to a red heat in any of the kinds of apparatus previously described, with the exception of the glass-retorts. The figure represents another form of the tube retort that is frequently used. Nitre consists of nitric acid and potassa, and when exposed to heat it is in the first place melted, and afterwards oxygen gas is evolved, which arises from the decomposition of the nitric acid. The latter consists of oxygen and nitrogen. Part of the oxygen is expelled, and nitrous acid remains in union with the potassa. The first portion of oxygen which escapes is comparatively pure, but afterwards it is loaded with nitrogen and various gaseous compounds of nitrogen and oxygen.
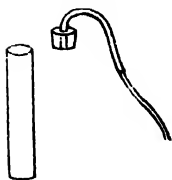
Fig. 22.

If the heat be too great or continued too long, the whole of the nitrous acid is decomposed, and a large quantity of gases is evolved, consisting of oxygen, nitrogen, nitrous and nitric oxides.

33. When nitre is used for the preparation of oxygen, the vessel in which it is contained should never be filled more than a third full, for when oxygen escapes from the melted nitre, the whole is thrown into a state of ebullition, and, were a larger quantity used, part would probably be thrown into the tube which conveys away the gas, and being immediately consolidated there (as it is at a much lower temperature than the melted nitre), would not only prevent the farther escape of gas, but might give rise to serious accidents from the accumulation of gas pent up in the interior of the vessel, and exerting a strong expansive force.

34. Oxygen gas is always prepared from the *chlorate of potassa* when it is required in a high state of purity, and is obtained from this substance by exposing it to heat in an iron or green glass-retort, and collecting it in the usual manner. A small green glass-flask with a long stem is occasionally

The figure represents the form of apparatus used by Mitscherlich.

employed, the stem being bent near the ball of the flask by the blowpipe, after the chlorate has been introduced.   An iron or gun-metal retort may be employed instead of the tube-retort. It is supported by a retort-stand, the body of the retort being allowed to rest on red hot cinders in a chauffer, and surrounded with more if necessary, using the tin pincers for this purpose. Fig. 7, page 5.

35. As the chlorate of potassa is melted by the heat before it parts with any oxygen, the precautions mentioned with respect to nitre in 33 must be carefully attended to.

36. Chlorate of potassa containing more than a third of its weight of oxygen, all of which is expelled by heat, affords a much larger quantity of this gas than any of the preceding substances.   Every 122.7 parts (one eq.) consist of 75.5 parts (one eq.) of chloric acid, and 47.2 parts (one eq.) of potassa.   The following table shews the composition of these two substances, and the quantity of oxygen evolved when 122.7 parts of the chlorate are exposed to heat.

Fig. 23.

:ːCl = 75.5 Chloric Acid	Oxygen 40 + 35.5 Chlorine = O⁵ + Cl.
K = 47.2 Potassa	= Oxygen 8 + 39.2 Potassium = O⁴ + K.

$$:ːCl = 75.5 \text{ Chloric Acid} \quad \text{Oxygen } 40 + 35.5 \text{ Chlorine } = O^5 + Cl.$$
$$K = 47.2 \text{ Potassa} \quad = \text{Oxygen } 8 + 39.2 \text{ Potassium } = O^4 + K.$$
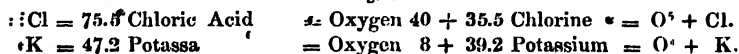
122.7 Chlorate of Potassa,   Oxygen 48   74.7 Chloride of Potassium.
Symb. :ːCl ·K = O⁶ & Cl K.

All the oxygen (48 parts) comes away both from the chloric acid and potassa, the chlorine of the acid remaining in combination with the potassium of the potassa, and forming 74.7 parts of the chloride of potassium.   The latter remains in the retort, and may be removed by water, which speedily dissolves it.

Fig. 24.
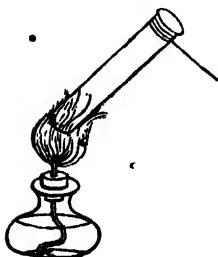
37. Oxygen gas may be easily prepared in a small quantity from the binoxide of mercury, or chlorate of potassa, by merely heating a few grains in a glass tube, the flame of a spirit lamp playing freely round it, as in the annexed figure (24).   It may be supported by a cord or piece of paper twisted round it.

38. If a splinter of wood red hot at the extremity be introduced into it, it burns

Fig. 25. with a lively flame; and if it be allowed to fall into the melted chlorate of potassa, a brisk deflagration takes place within the tube, in the manner shewn in fig. 25.

39. There are several other substances, of a similar nature, from which oxygen gas may be procured, but they are seldom employed for this purpose. Small quantities may be obtained also when the green leaves of vegetables are immersed in an inverted jar full of water, and placed in the sunshine.

40. Oxygen gas, in its pure state, is not applied to any practical purpose on the large scale ; it is used constantly, however, in the laboratory for a number of important and interesting experiments; it will accordingly save much time and trouble on commencing a series of experiments, if a large quantity be prepared in the manner described in 16. &c.

41. Flexible tubes are required for conducting the gas from the gasholder to the pneumatic trough. These should not be made of lead or tin, as they are never required to stand a high temperature, but merely for the transmission of the gas after it has been prepared. They are in general made of a coil of wire surrounded with several folds of varnished silk, one end being fitted to the stop-cock of the gasometer, and the other placed in the pneumatic trough, or connected with a second flexible tube, if the first should not be sufficiently long.*

42. In effecting combinations between oxygen and other substances, the compounds usually employed to afford it are atmospheric air, water, and acids. Bodies in general require to be heated before they combine with oxygen. Some, however, as potassium, abstract it rapidly both from air and water at natural temperatures.

43. By the conjoined action of air and moisture, many substances are readily oxidated. Iron, for example, soon passes into rust, and the sulphate of iron or green vitriol of commerce is prepared from the native sulphuret of iron in this manner, the sulphur being converted into sulphuric acid while the iron is oxidated.

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* These flexible tubes may be procured at the principal opticians and philosophical instrument makers in town.

44. A number of the metals attract oxygen from water at a red heat. At ordinary temperatures, the oxidation goes on briskly if some acid be added, as the sulphuric or hydrochloric, while the hydrogen (the other element of which water is composed) is disengaged. It is in this manner that hydrogen gas is usually procured.

45. When acids containing much oxygen are poured in a concentrated form on substances that have a great affinity for this element, as metals and inflammable bodies, oxygen is rapidly taken from them, especially if the action of the decomposing agent be assisted by heat. Thus, mercury poured into nitric acid is speedily oxidated, and if boiled in sulphuric acid the same thing takes place. In both cases, however, the oxide formed by the decomposition of one portion of the acid unites with another portion that has not been decomposed, and the resulting products are a nitrate and a sulphate of the oxide of mercury.

46. When oxygen is to be withdrawn from any substance which does not part with it on exposure to heat, it is usually mixed with charcoal, which, at a high temperature, has a much greater affinity for oxygen than most other substances. It is in this manner that most of the common metallic oxides are deoxidated, and their bases procured in the metallic form; the carbon combining with the oxygen, and being carried off in the form of carbonic oxide or carbonic acid gas. Hydrogen, Phosphorus, and Potassium are also used as deoxidating agents.

CHAP. II.—HYDROGEN.

Symb. H ; *Eq. by* W. 1 ; *by volume* □ *(one measure.) Sp. gr.* 0.0689. W. *of* 100 *c. i.* 2.137 *grs.* 100 *c. i.* of water absorb .1.56 of Hydrogen.

47. Hydrogen is another element that is extensively distributed over the face of nature, forming a ninth part of the water of the globe, and existing in almost all the products of the animal and vegetable kingdom. It is always obtained in the form of a transparent and colourless gas, when not combined with any other substance, and is distinguished by its great levity and inflammability.

48. Hydrogen gas is always prepared for experimental purposes by decomposing water, a compound of hydrogen and oxygen ; the oxygen being withdrawn by the action of some substance which has a great attraction for it.   Iron and zinc are usually employed for this purpose, and the most convenient method of conducting the process is to put the iron or zinc into a glass retort supported on a stand in the manner represented in Fig. 2, or into a glass flask of the form shewn in the annexed figure, a cork being fitted to the neck, through which a bent glass or leaden tube passes, intended to convey the gas as it is evolved into a gasometer, or to dip under the shelf of the pneumatic trough.   When the apparatus is properly adjusted, sulphuric acid diluted with 6 or 7 parts of water is poured over the metal through the tubulure at the side, and as hydrogen gas is immediately evolved, the stopple must be introduced and the gas collected when the atmospheric air has been expelled.   A common phial or beer bottle, with a bent tube adapted to it, may be used when no other apparatus can be procured.

Fig. 26.

49. Instead of the glass tube passing through a cork placed in the neck of the flask, it is often made thicker at the part where it is connected with the flask, and ground to it accurately in the same manner as a stopple.   The flask is supported on a ring made of tin or copper, Fig. 27, or on a square block of wood with a hole cut in the centre, as is seen in Fig. 28.
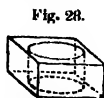
Fig. 27.   Fig. 28.

50. Any glass bottle may be used as a substitute for a flask in the preparation of hydrogen gas ; a bent tube being adapted to it in the manner shewn in Fig. 29.   On the large scale, vessels of lead or beer barrels are generally used.

Fig. 29.

51. The vessel in which the hydrogen gas is prepared ought never to be filled more than a third full, as it is frequently disengaged so rapidly as to cause the liquid to boil over.   The rapidity with which the gas comes over depends not only on the quantity of the materials employed, but also on the state of division of the metal, and the extent of surface which it presents to the water and the acid.

The quantity of sulphuric acid required for the preparation of hydrogen gas depends upon the nature of the metal employed. The following diagram shews the proportions in which the materials react with each other when zinc is used.

Fig. 30.

Materials employed.   Resulting products.

·H = 9 Water { Hydrogen 1 -- ----·---------- 1 Hydrogen = H.
              { Oxygen   8__₀
Z = 32.3 Zinc,............   32.3.
:S = 40.1 Sulphuric acid,́ 40.1————————➤80.4 Sulphate of Zinc = :S·Z.
          Symb. Z & :S+·H = :S·Z & H.
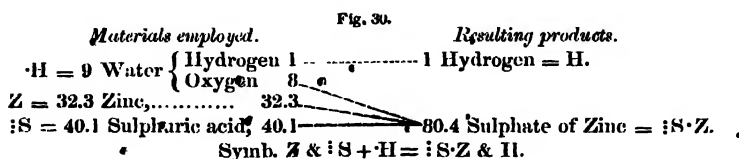
The 8 parts of oxygen contained in the 9 parts of water combine with the 32.3 of zinc, and form 40.3 parts of the oxide of zinc. This unites with the sulphuric acid, while the hydrogen of the water is disengaged! But the sulphuric acid must be mixed with more water than is decomposed during the preparation of the gas, otherwise little or no action takes place ; for the sulphate of zinc produced must have a sufficient quantity of water to retain it in solution, that it may not be thrown down in the form of a powder, and impede the farther action of the metal upon the liquid. And, as every 49.1 parts of the common sulphuric acid contain only 9 of water, we may use by weight, 7 parts of zinc, 10 of sulphuric acid, and 60 of water.

52. When iron is used, the same quantity of sulphuric acid and water may be mixed with 6 parts of this metal. The theory of the process is precisely similar to what has just been stated with respect to the preparation of hydrogen by zinc, the iron being oxidated and uniting with the sulphuric acid, while the hydrogen arising from the decomposition of the water which affords oxygen to the iron is disengaged, 28 parts of iron (one equivalent) acting upon 9 parts of water and 40.1 of sulphuric acid in the same manner as 32.3 of zinc. Symb. Fe & :S+·H = :S·Fe & H.

53. Accordingly, in calculating the quantity of hydrogen gas disengaged by the action of a given weight of zinc or iron, we may allow 1 grain of gas for every 32.3 grains of zinc (or 28 of iron) employed ; and, as 47 cubic inches weigh very nearly 1 grain, if we multiply the weight of the hydrogen that ought to be disengaged (expressed in grains) by 47, we have the volume which it will occupy in the gaseous state expressed in cubic inches.

54. As hydrogen gas detonates violently when mixed with atmospheric air or oxygen gas in certain proportions, a lighted match must never be applied to it as it issues from any apparatus where it may have mixed with either of these gases. This must be carefully attended to in preparing it by the process just described, serious accidents frequently taking place from not observing this precaution, the flame being communicated through the tube to the mixed gases in the interior of the apparatus, upon which an explosion-takes place. The best method of ascertaining when the atmospheric air has been expelled, is to collect a small jar of the gas over a pneumatic trough, remove it on a plate or tray, keeping the mouth still downwards, and apply a lighted match to the gas as the tray is withdrawn, still keeping the jar in the same position. If it be mixed with atmospheric air it will burn rapidly, but if the air shall have been completely expelled, the hydrogen will burn slowly, and only where it comes in contact with the air.

55. When iron is employed for the preparation of hydrogen gas, it may be used in the form of turnings or filings. Small nails are occasionally substituted for them, or iron wire cut into pieces from 1 to 3 inches long. Zinc is easily reduced to fragments by melting it in a crucible or iron ladle over the fire, and pouring it from a height of several feet into a basin of water. If the zinc be poured into water as soon as it is melted, small solid spherules are obtained, which dissolve slowly and steadily in the diluted acid. But if the zinc be heated beyond its melting point before allowing it to fall into the water, it spreads into thin laminæ, which dissolve more speedily from the greater extent of surface which they present.

56. Another method of preparing hydrogen consists in passing watery vapour over bright iron wire or turnings heated to redness. These are put into an iron tube or gun-barrel about 18 inches or 2 feet long, open at both ends, and made to traverse a furnace. A retort containing water is attached to the gun-barrel, covering the beak with a roll of cotton-cloth on which chalk lute has been spread, and securing the joint afterwards in the same manner. A bent brass or copper tube with an iron head, fitted by grinding to the other end of the gun-barrel, is then adapted to it so as to convey away the gas.

Instead of a furnace, a chauffer may be employed when the process is conducted on a small scale, in the manner shewn in
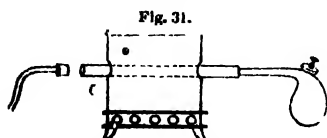
Fig. 31.

Fig. 31. A chimney (page 5, par. 11) will assist materially in keeping up the proper temperature; and the chauffer may be raised to any height by supporting it on bricks.

57. When the gun-barrel is at a red heat, the water in the retort is made to boil, and the steam passing over the iron at this high temperature is immediately decomposed, the hydrogen escaping in the gaseous state and passing through the bent tube, while the oxygen combines with the iron. Nine parts of water require 28 of iron for decomposition, 36 parts of oxide of iron being formed, while 1 of hydrogen is evolved.

58. Instead of connecting a retort containing water with one of the ends of the gun-barrel, it may be bent in the manner

Fig. 32.

shewn in the annexed figure, a funnel made of copper or tinned iron, and terminating in a stopcock, being afterwards fixed to it. Water is poured into the funnel, and when the gun-barrel is at a red heat, the stopcock is opened and immediately shut again; a small portion of the water is thus allowed to run down into the gun-barrel, and being converted into vapour by the heat, is immediately forced over the iron shavings and decomposed. This is repeated until a sufficient quantity of gas is obtained. The water must be allowed to pass into the tube only in small quantities at a time, otherwise the temperature of the turnings may be so much reduced that the watery vapour passes over them without being decomposed.

59 Fig. 33 is a variety of this apparatus, consisting of a cast-iron tube with a funnel at one end, and leaden tube at the other, both of which can be removed when the iron in the apparatus is to be renewed.

Fig. 33.
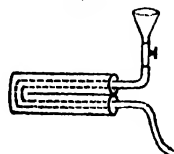
In using this apparatus it ought not to be exposed to a very high temperature, as a red heat is quite sufficient for the purpose, and all kinds of iron tubes are soon destroyed when exposed to the action of the air at a high temperature; the gun-barrel should not be left till the fire has burnt away, but withdrawn from the furnace when the bent

tube which conveys the gas to the pneumatic trough has been removed.

60. When hydrogen gas is prepared by this process on the large scale, the iron turnings are generally put into a very large iron retort, such as is used at gas-works, and the vapour of water passed over them.

61. Hydrogen gas is occasionally collected in a gasometer of a different construction from the gasholder described in 21. It consists of a vessel of japanned tinned iron, Fig. 34, AA, sup-

Fig. 34.

ported on feet, and filled with water. In it another vessel C, made of the same substance, is placed in an inverted position. To diminish the quantity of water required for this apparatus, the interior of the outer vessel is filled up in a great measure by an inner vessel BB, from the top of which a tube passes to the bottom, and divides into two branches which open on opposite sides of the outer vessel, as is seen at e and f. When the gasometer is to be filled, a tube conveying the gas is fixed at f, and the bell-shaped vessel C rises up as it enters, being suspended by cords passing over pulleys, and counterpoised by weights. The rod g attached to the bell-shaped vessel being accurately graduated, the quantity of gas the gasometer may at any time contain is found out by examining the point at which the rod is cut by a bar through which it is made to pass.
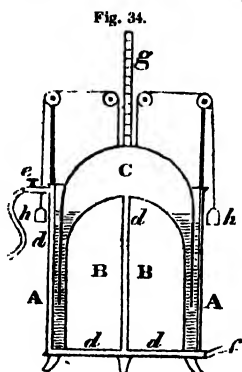
62. Instead of connecting the tube which conveys the gas di-
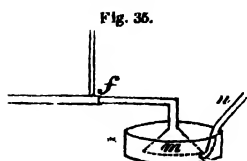
Fig. 35.

rectly with the gasometer it is sometimes more convenient to introduce it under a funnel, Fig. 35, placed in a basin and screwed on at f, the gas rising in the funnel and passing into the gasometer, the water being put into the basin to prevent it from escaping.

The gas in the interior may be expelled by shutting the stopcock at f, and opening the stopcock e, the counterpoising weights being at the same time removed; the bell-shaped vessel descending by its own weight forces the gas out at e.

63. Fig. 36 represents a very convenient apparatus for pre-
paring a small quantity of hydrogen whenever it may be re-
quired.   It is a bottle with three tubulures, a long
tube funnel being fixed into one, and descending
till it comes within an inch and a half of the bot-
tom, and a bent tube adapted to one of the others.
Fragments of zinc and water are put in by the
middle tubulure, till the fluid shall have risen about
half an inch above the lower end of the tube fun-
nel; the cork or stopple is then put in, and on
pouring sulphuric acid down the long tube funnel,
it mixes with the water, hydrogen gas is imme-
diately disengaged, and may be conveyed in any direction by
the bent tube fixed in the tubulure.   The diluted acid is forced
up the long tube funnel to a height proportional to the depth
that the bent tube is introduced into water.   If the bent tube
were sunk to a considerable depth in water, and the tube fun-
nel made very short, then the gas might have to overcome a
greater resistance in rising through this depth of water than in
forcing the liquid in the bottle up to the top of the tube funnel; ,
it would accordingly continue to flow over till the liquid in the
bottle should fall below the lower part of this tube, and allow
all the gas to escape.   •   ‘
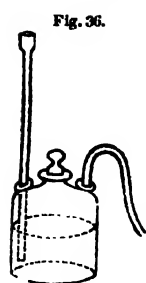
64. If small quantities of sulphuric acid be poured into this
apparatus from time to time after putting in a supply of zinc
and water, a constant stream of hydrogen gas may be made to
issue from the bent tube; and it is in this manner that hydro-
gen gas is usually prepared, when it is required to transmit it
over any substance exposed to a red heat in a gun-barrel or
porcelain tube.

65. The gas obtained by these different processes is not ab-
solutely pure, having a disagreeable odour when disengaged
during the solution of iron in diluted sulphuric acid, and con-
taining minute traces of hydrosulphuric acid when zinc is used.
The odour is attributed to the presence of a little carburetted
hydrogen, derived from oil attached to the iron turnings, or form-
ed by the union of part of the carbon, which common iron al-
ways contains, with a little hydrogen.   The zinc of commerce
always contains a portion of iron and sulphur, which explains
the formation of the small portion of hydrosulphuric acid ; and

a part of the zinc also, it has been affirmed, combines with the gas. By passing it through a solution of potassa or lime water, most of the impurities may be removed, with the exception of a small portion of carburetted hydrogen, which has been detected in hydrogen gas prepared by iron.

66. Zinc that has been frequently distilled is preferred for the preparation of hydrogen gas when it is required in a very high state of purity for experimental researches, but it dissolves very slowly. The rapid solution of common zinc is attributed to an electric action induced by the minute portions of other metals which it contains.—(*Arago.*)

67. Hydrogen gas burns with a very pale reddish looking flame, which affords a very feeble light. To observe the character of the flame, apply a lighted match to a jar containing the gas, so that it shall burn with the mouth downwards ; the hydrogen is slowly consumed as it comes in contact with the atmospheric air.

Fig. 37.
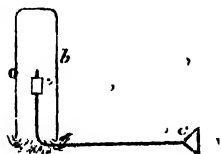
68. If a candle be tied to a piece of iron-wire bent at right angles, and introduced, when lighted, into a jar of hydrogen gas held with the mouth downwards, the hydrogen is inflamed and continues to burn at the mouth of the jar, while the candle is extinguished in the interior of the jar where it is surrounded by the hydrogen. This proves that the presence of air or oxygen in some form or other is necessary for its combustion, the gas burning only where it comes in contact with the air, and the hydrogen, from its great levity, occupying the upper part of the jar till it is all consumed. See Fig. 37.

69. Inflame another jar of hydrogen gas with the mouth turned upwards, taking care not to remove the cover till the light has been brought over the top of the jar ; it burns much more rapidly than before, rising quickly in the air, and mixing speedily with as much as may be required for its combustion. If the cover be removed for a short time before the light be applied, the gas soon escapes, and the jar is filled with common air.

70. Hold two jars perpendicularly, one being full of air, and the other full of hydrogen gas. Then place the jar with the hydrogen under the other as in Fig. 38. It escapes into the upper jar, where it may be afterwards inflamed. The experimenter

need not expect to succeed if the air be
very much agitated at the time he is ope-
rating. He should avoid all local cur-
rents and not breathe in the direction of
the jar.

71. In all these experiments the hydro-
gen unites with the oxygen of the air, form-
ing watery vapour, which mixes with the air
or condenses into water.

72 Mix one measure of hydrogen gas with half its volume
of oxygen gas, and fill a strong glass-bottle with the mixture.
Cork it under water, and after wrapping a towel round it,
apply a lighted candle or piece of paper to the mouth of the
bottle on withdrawing the cork. A quick and loud explosion
instantly takes place, the oxygen and hydrogen combining as
before, and forming watery vapour which is immediately con-
densed. In performing this experiment, a strong bottle
made on purpose should be employed, capable of con-
taining from three to six ounces of water, as it is sel-
dom that a flint-glass bottle, of the usual strength, will
stand the explosion. The reason why the gases are
mixed in the above proportions will be seen on refer-
ring to the table of equivalents by weight and by measure.

Fig. 39.

	Hydrogen.	Oxygen.	
Equivalents by weight	1 +	8	= 9 water.
Corresponding equivalents	⊡ +	▯	= ▯ watery vapour.

73. Here, it is seen that one equivalent of hydrogen by
weight (= 1) corresponds with one measure or volume of hy-
drogen gas, and that one equivalent of oxygen by weight (= 8)
corresponds with half a measure, oxygen gas being sixteen
times heavier than hydrogen gas; and by their combination
one volume of watery vapour is produced, a condensation
taking place equal to the volume of the oxygen employed. If
an excess of either gas be present, it remains after the deto-
nation.

74. Atmospheric air containing one-fifth of its volume of
oxygen gas, every measure of hydrogen gas requires 2½ mea-
sures of air for its combustion; the detonation that ensues is
very feeble compared with what takes place when the hydrogen
is mixed in the proper proportion with oxygen gas. A small
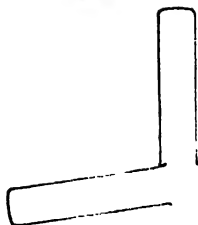
excess of atmospheric air causes a louder detonation than when the exact quantity required for the combustion of the hydrogen is employed. By varying the proportion of air or oxygen gas mixed with the hydrogen, before the light is applied, and holding the jar or detonating bottle containing the mixture in different positions, the rapidity of the combustion and the appearance of the flame are considerably varied.

75. A piece of paper folded into a match will be found more convenient than a candle for firing the hydrogen in these different experiments.

76. The detonating mixture is made most conveniently by placing any jar or phial full of water on the shelf of the pneumatic trough, filling it twice with hydrogen, transferring it each time to a larger jar; it is then to be filled with oxygen, which is to be mingled well with the hydrogen; the detonating bottle is then to be filled with this mixture.

77. In transferring the detonating mixture to the strong bottle, it may be placed above an aperture in the shelf of the pneumatic trough, as shewn in Fig. 40; or should the phial be very small, it may be held
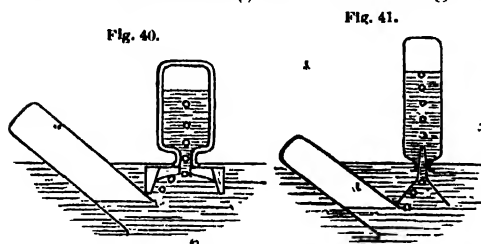
Fig. 40.

Fig. 41.

in the left hand with a funnel under water, Fig. 41, the gaseous mixture being transferred by the right hand; very small portions should be introduced into the funnel at a time.

78. In examining generally the manner in which any gas burns or supports combustion, it is not always necessary to fill the jar full before applying a lighted match; it is essential, however, both in operating with the gas for particular purposes, and in preliminary trials, to retain any water b, not previously expelled, both when the cover is slipped under the jar, and when the jar is inverted.
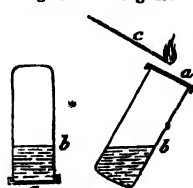
Fig. 42.

Fig. 43.

79. In firing detonating mixtures, the match c is usually placed over the mouth of the bottle or jar, as in Fig. 43, before the cork or cover is withdrawn.

80. Oxygen and hydrogen do not combine so readily when

they are, expanded by diminishing the pressure to which they are exposed; if the pressure be increased, they unite with greater facility, and when mixed in the proper proportions and suddenly compressed, they immediately combine, a loud detonation taking place. If part of the vessel be made of glass, a brilliant light is seen, and the vessel is generally broken. This experiment was made by Biot, but it is not easily performed, and always dangerous. The heat evolved during the compression has generally been considered as the cause of the combination.

81. A mixture of oxygen and hydrogen may be made to combine slowly and without any detonation, by introducing a piece of coal at a dull red heat; if it be at a bright red heat an explosion always takes place.

82. Into a six or eight ounce phial, introduce a mixture for the preparation of hydrogen gas; fit a tube with a small aperture to it, and when the air shall have been expelled by allowing the hydrogen to be disengaged for some minutes, kindle the gas at the extremity of the tube. If tubes of glass be now held over it, Fig. 44, very shrill tones are produced. A small stream of hydrogen may be produced for the same purpose at the extremity of a flexible tube connected with a gasometer.

Fig. 44.

83. When a stream of hydrogen gas (issuing from a gasometer or any other source) is directed upon a piece of spongy platinum, (metallic platinum in a very minute state of division), it immediately becomes incandescent if atmospheric air or oxygen gas be at the same time present, and the hydrogen is almost instantly inflamed. The spongy platinum may be supported in a small cage of platinum wire; this is not necessary, however, for though the effect is seen to greater advantage in this manner, the incandescence of the platinum and the inflammation of the gas take place whenever they come into contact (along with air), whatever may be the nature of the substance on which it rests. If the platinum should be damp, it must be carefully dried by exposing it to heat in a crucible, or in a small plate of metal held over a spirit-lamp.

84. This singular property of platinum was discovered by Professor Doebereiner, and a lamp for procuring an instantaneous light constructed on this principle is well known by the

Fig. 45.
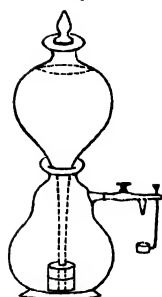
name of Doebereiner's Lamp. Fig. 45. It consists of an ingenious contrivance of Gay Lussac's, by which a jet of hydrogen can be obtained instantaneously by merely opening a stopcock, a brass cup being fixed below it to contain the platinum. The hydrogen gas is produced by the action of a cylinder of zinc on diluted sulphuric acid placed in the lowermost vessel represented in the annexed figure, the acid being diluted with about fifteen times its weight of water. The upper part consists of a globe nearly as capacious as the first, and capable of containing from about 60 to 100 cubic inches, but terminating in an open tube which is fitted accurately to the neck of the other by grinding. The cylinder of zinc is placed round this tube, supported about a quarter or half an inch above its inferior extremity by a cork that also fits closely to the tube. When the cylinder is introduced into the lower vessel, hydrogen gas being immediately evolved, and not finding any exit when the upper one is properly adjusted, it collects at the top of the lower vessel, and presses upon the surface of the liquid below, which is consequently forced through the tube into the upper vessel. If the stopcock connected with the lower vessel be now opened, the liquid that has been forced into the upper one will descend, and force out the hydrogen gas, by the small nozzle, fixed so as to direct it upon the platinum; while the liquid, coming again into contact with the metallic zinc, more hydrogen will be produced, until at last the zinc is dissolved, or all the sulphuric acid converted into sulphate of zinc.

85. The stopple in the upper part of this apparatus must have a groove cut in the side to allow the free ingress or egress of air, and the cup containing the platinum must be supported by a wire sliding through a piece of brass attached to the stopcock, so as to allow it to be brought nearer or removed farther away from the aperture by which the hydrogen escapes. When more sulphuric acid is required, it is necessary to dilute it previously with twice its bulk of water, and allow it to cool; for if strong sulphuric acid be poured into the upper vessel after withdrawing the stopple, the heat produced when it mixes with the liquid frequently causes the glass to break.

86. When neither a gasholder nor an apparatus such as Doebereiner's lamp are at hand, the effect of the gas upon the spongy platinum may be seen by filling a bladder with hydrogen, and compressing it afterwards, so as to force out the gas in a slender stream. For this purpose the bladder must be provided with a stopcock, and a brass nozzle fitted to it, which is to be fixed on when the bladder is full. A pneumatic jar, provided with a stopcock, must also be procured, and a connector, as it is termed, or small tube open at both ends, by which the bladder and the jar can be connected together by the stopcocks, as represented in Fig. 46. Both stopcocks being now shut, and the jar placed full of water on the shelf of the pneumatic trough, hydrogen gas may be introduced, and by depressing it in the pneumatic trough, and opening both stopcocks, the gas is forced from the jar into the empty bladder by the pressure of the water.

Fig. 46.
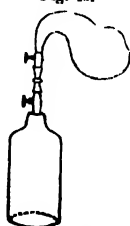
87. On removing it from the connector and the pneumatic jar, the brass nozzle, terminating in an aperture not exceeding one-fiftieth of an inch in diameter, must be fixed to it, which will prevent too large a quantity of hydrogen from being expelled on turning the stopcock and compressing the bladder.

Fig. 47.

88. Oxygen and hydrogen gases, when mixed in the proper proportions, are inflamed by the spongy platinum as rapidly as by a flame, or by an iron rod at a white heat. If a bladder be filled with a mixture of the two gases, and a piece of spongy platinum introduced, they immediately explode with great violence, and the bladder is blown to pieces. For this experiment, fit a large perforated cork to the neck of the bladder; through this the spongy platinum is introduced, supporting it in a small wire cage attached to an iron wire which is fixed to another cork that fits the aperture in the first. When the bladder has been filled with the mixture, a common cork is immediately put into it to prevent the escape of the gas. On removing it to a safe place, where it may be supported on a retort-stand, this cork is taken out, and the other with the platinum attached to it immediately introduced, a glove being put on the hand in which it is held, in case it should explode as it is put in.

89. A simpler mode of shewing this effect consists in filling a small and stout detonating jar with the explosive mixture, lifting it perpendicularly with the left hand, and introducing a platinum ball tied with a little iron wire to a stouter wire bent at right angles. The whole arrangement is similar to Fig. 37, the platinum ball replacing the candle, and the bent wire allowing the hand to be held at some distance from the jar.

90. Should the jar in which the experiment is to be performed be required perfectly dry, it must be filled at the mercurial trough, or by displacement. In the latter case, a capped jar a is charged with the detonating mixture, depressed in water, and the gaseous mixture made to displace the air in b, as it escapes on opening the stopcock. The platinum may then be introduced.

91. When the gases are mixed in different proportions, or when the oxygen and hydrogen, though present in the exact proportions in which they combine with each other, are mixed with other gases, the detonation does not take place, or, at least, only after some time has elapsed. The platinum always causes them, however, to combine, and the heat generated during the combination is so great, that the platinum frequently becomes incandescent, though the mixture be not inflamed. The spongy platinum retains this property even when mixed with clay, and made into small balls. They are, made with different proportions of platinum, and are more or less active, according as the quantity of platinum is increased or diminished. The method of preparing the spongy platinum, &c. will be described under *Platinum.*

92. As oxygen and nydrogen combine in the proportion of half a measure (⊐) of the former to a whole measure (□) of the latter, forming watery vapour, which is immediately condensed if the temperature be not kept at 212°, it is obvious that we can estimate the proportion of oxygen or hydrogen in mixed gases, by adding one, or other of these to the mixture, and noting the degree of condensation that attends the combination. For example, if we wish to ascertain the purity of hydrogen gas, prepared by any of the preceding processes, a small portion

may be mixed with its own volume of oxygen gas in a graduated
jar or tube over a mercurial trough, and a ball of platinum in-
troduced, previously mixed with clay, however, to prevent any
detonation.   If a condensation takes place equal to the bulk of
the hydrogen and half of tho oxygen employed, then we are sure
that the hydrogen gas is pure, for oxygen and hydrogen com-
bine in these proportions ; if, however, it does not take place
to this extent, then, on noting the amount, and taking two-
thirds of it, this expresses the exact quantity of pure hydrogen
contained in the portion under examination.   The tube or jar
containing the gases must always be elevated or depressed in
the mercury, so that it shall be at the same level within and
without, when measuring the quantity employed or the amount
of condensation.

93. In the same manner, the purity of oxygen gas may be
ascertained by mixing an excess of pure hydrogen with a given
quantity of the oxygen gas, and proceeding as before.   If the
diminution of volume in the mixed gases be equal to three times
the bulk of the oxygen employed, it is evident the oxygen must
have been pure, for it combines with twice its bulk of hydrogen ;
if, however, the condensation does not proceed so far, then one-
third of the amount to which it does take place, indicates the
exact quantity of pure oxygen in the portion employed.

94. In performing these experiments, should the mercurial
trough be shallow, after the ball has been introduced by a pair

Fig. 49.   Fig. 50.   Fig. 51.
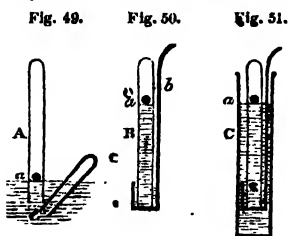
of pincers, Fig. 49, an iron or por-
celain cup, Fig. 50, suspended by
a strong wire, may be introduced
under the tube, and used as a tray
to remove it to a tall and narrow
jar, in which, when the action is
completed, the precise amount of
condensation may be observed, by

placing it so that the mercury shall be on the same level, both
within and without, Fig. 51.

95. A bent tube ab, filled with mercury (Fig. 52), may
be used as a substitute for a mercurial trough when carefully
supported.   The gases to be employed being introduced by a
smaller tube e when the proper proportions have been mixed,
the platinum ball d is then introduced.   Mercury is poured

into the open limb as the operation ad-
vances.

Fig. 52.

96. In experiments with this tube, if
the open extremity be full of mercury, it
is easy, by a little management, to turn
it so that a small portion of gas shall pass
to that side, to which a flame, a portion
of water, or any other test, may be ap-
plied, according to the nature of the gas, the remainder being
still retained in the sealed extremity of the tube.
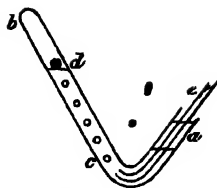
97. Mixtures of hydrogen and oxygen gases may be inflamed
also by the electric spark. See *Electricity.*

98. Hydrogen gas produces an intense degree of heat during
its combustion, and if mixed with oxygen gas in the proper
proportion, and made to issue from a small orifice, we have at
our command a more powerful heat than can be produced in any
other way. It is on this principle that the oxy-hydrogen blow-
pipe is constructed, which will be described when we come to
treat of the blowpipe.

SECT. 1.—WATER.

Symb. H ; *Eq. by* $W.$, 9 ; *by volume* $\square$ *(one measure).* *Specific
gravity,* 1.000. *One cubic inch weighs* 252.458 *grains at* 62°
Fahr., Bar. 30° ; *it is about* 815 *times heavier than air, and
when converted into vapour at* 212°, *it expands to* 1696 *times
the volume it occupies at its greatest density. The specific gravity
of steam (air at* 212° *being* 1 *) is* 0.625 ; *or* 0.484, *air at* 60°=1.

99. When a mixture of half a measure of oxygen gas ($\square$)
with one measure of hydrogen ($\square$) is inflamed in a dry glass
vessel, both gases entirely disappear, and the interior surface
of the vessel is found bedewed with moisture, formed by the
condensation of the watery vapour that results from the com-
bination. To see this distinctly, the dry gases must be mixed
in a proper detonating bottle (77) over a mercurial trough. Or
a stream of hydrogen gas may be inflamed as it is made to issue
from a gasometer through a flexible tube, to which a brass
nozzle with a small aperture has been fitted, and introduced

into a large glass flask or jar, taking care not to bring the flame too near the glass.

100. If a mixture of oxygen and hydrogen gases were made at the temperature of 212°, and the apparatus not allowed to cool after the detonation, one measure of steam would be formed a condensation, equal to the volume of oxygen employed, accompanying the combination.

101. There is perhaps no agent of more importance, in a practical point of view, than water, when we consider its mechanical and chemical properties, and the infinite variety of purposes to which it may be applied. It not only enters into combination with many substances, forming a well defined series of compounds termed hydrates, but is also the medium by means of which many important combinations and decompositions are effected, as in the decomposition of compound salts, where it communicates that fluidity without which they often do not act on each other. From the extensive range of the affinities of its elements, and the facility with which they are separated by peculiar arrangements, it is constantly giving rise to new combinations; while, by others, of a different nature, these are subverted, and the oxygen and hydrogen again unite to form water. Certainly no department of chemistry is more interesting than the study of the different changes of which this fluid is susceptible, and the combinations arising from its decomposition, or attending its formation, which accompany the action of a great number of substances upon it, and upon one another. This is well exemplified in the changes that take place in the chlorides, iodides, bromides, and cyanides, and water, when one of the stronger acids is added to them, and also in the preparation of oxide of nitrogen, protoxide of chlorine, chloric acid, hydrosulphuric acid, and many other substances, where water is either formed or decomposed. By the researches of modern chemistry, especially those more immediately connected with the examination of the chemical equivalents of the different elements and their compounds, these actions have been traced with a degree of minuteness and precision which has been attended with the happiest results; and instead of being considered as complex phenomena, the method in which the different particles arrange themselves may now be studied with facility and satisfaction, even by the beginner.

102. Pure water being constantly required for experimental purposes, it is necessary to state the characters by which it may be known, and the method of obtaining it, as, in its native state, this fluid is always contaminated with some foreign matter, according to the channel through which it may have flowed, and the particles of mineral, vegetable, or animal matter with which it may have come in contact.

103. The purest water that can be obtained, without subjecting it to artificial operations, is procured by melting snow, or collecting rain as it falls at a distance from towns, or in any place where it is not liable to be vitiated by the state of the atmosphere. Even this, however, is not perfectly pure, for it contains a portion of air, which may be disengaged by boiling it, or placing it under the exhausted receiver of an air-pump.

104. It will be found most convenient in general to prepare pure water by distillation, the only method indeed by which it can be completely separated from the saline matter which it usually holds in solution. The apparatus commonly used for this purpose is a small boiler of tinned iron (Fig. 53), 6 or 7 inches in diameter, and about 7 or 8 inches deep. It is filled half full of water by the funnel *a*, which is soldered in it, and descends till it comes within an inch of the bottom; the steam is conveyed by a tin tube (*b*) to another tube coiled in a spiral form in a vessel of water, termed the refrigeratory, where it is condensed, and may be collected in a bottle as it drops from the other extremity of this tube. The boiler is heated by placing it in a furnace, or over the open fire.
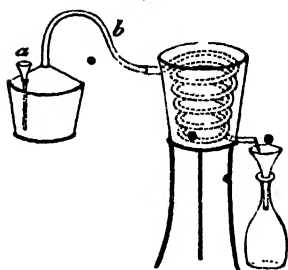
Fig. 53.

105. The vapour must be allowed to escape for a short time before any is collected, to expel any gaseous matter which it may contain, as well as to remove any foreign matter that may be adhering to the sides of the tube; after three-fourths of the water have been distilled over, the remainder had better be thrown away. When the level of the water in the interior of the boiler falls below the lower part of the funnel, the steam then issues through the tube of the funnel, and informs us of the extent to which the evaporation has been carried. More

water may then be poured in by the funnel, or a fresh charge introduced after the remainder has been set aside.

106. It is seldom necessary to distil water in glass vessels, except perhaps in very delicate experimental investigations, or where an apparatus such as has been described is not at hand. A plain retort may then be used for this purpose, condensing the vapour in a thin glass receiver or Florence flask, Fig. 54.

Fig. 54.

The retort is supported by a common retort stand (see Fig. 2, page 3), and heated by a chauffer or lamp. The receiver is kept cold by surrounding it with a piece of cotton cloth, and allowing a stream of cold water to fall upon it through a funnel, the throat of which is obstructed with a little tow, or by a stream from a small syphon. Instead of glass, vessels of silver have been recommended.

107. A long funnel (Fig. 55) is preferred for introducing the water, so as to prevent any undistilled water from passing to the receiver from the neck of the retort. When a tubulated retort is employed the funnel is unnecessary.

Fig. 55.
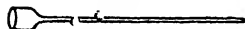
108. Pure water is perfectly transparent and colourless, and remarkably limpid, though it has not that fine sparkling appearance which water impregnated with gaseous matter always presents when it is poured from one vessel to another. To the taste it is insipid and unpleasant. Its specific gravity is less than that of water containing saline matter in solution; it mixes easily with soap, gives no precipitate with a solution of soap in alcohol, nitrate of silver, hydrochlorate of baryta, or acetate of lead, and has no action on litmus or lime water. It also moistens bodies more easily and more thoroughly than water which has any foreign matter in solution.

109. A general idea of the amount of foreign matter, not vo-

Fig. 56.

latile, in any water, may be obtained by evaporating slowly one or two drops on a slip of glass carefully washed previously in

distilled water. If it be very pure, little or no trace will be left, except of very minute rings. If less pure, the rings are thicker, and if very impure, a continuous crust appears.* The above Fig. (56) will illustrate the appearances presented by different waters evaporated in this way.

110. As water readily absorbs a number of gaseous substances, especially when it has been boiled to expel any air that may have been combined with it, distilled water must be kept in glass bottles with ground stopples, otherwise it is soon contaminated by the different gases that are constantly floating about in an experimental room. The following table by Dr Henry shews the quantity of several of the gases which 100 cubic inches of water can absorb at the usual temperature and pressure.

	Dalton.					Saussure.
Sulphureted Hydrogen	100	cubic inches,	.	.	.	253
Carbonic Acid . .	100	do. .	.	.	.	106
Nitrous Oxide . .	100	do. .	.	.	.	76
Olefiant Gas . .	12.5	do. .	.	.	.	12.3
Oxygen . . .	3.7	do. .	.	.	.	6.5
Carbonic Oxide . .	1.56	do. .	.	.	.	6.2
Nitrogen . . .	1.56	do. .	.	.	.	4.1
Hydrogen . . .	1.56	do. .	.	.	.	6.4

111. Distilled water should always be employed in preparing solutions for experimental purposes; and when these are to be used as re-agents, attention to this circumstance is quite indispensable, as the presence of the smallest portion of foreign matter might lead to an erroneous conclusion.

112. In examining boilers for the production of steam, many points require minute attention, which may be studied most satisfactorily with the aid of a small copper model from six to ten inches in diameter, heating it cautiously by a lamp or furnace.

In Fig. 57, *a* and *b* represent the interior of the boiler filled to the dotted line between *a* and *b* with water; *c* the feed pipe for supplying water; *d* the steam pipe; *f* and *g* pipes within the boiler terminating without in stopcocks; these descend to unequal depths within, being of such length that when the boiler is properly charged with water, on opening *f* nothing escapes

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* Under "Mineral Waters," the method of examining for the various ingredients they contain will be described. Until the beginner is familiar with a number of tests, he could not enter upon this subject with advantage.

Fig. 57.
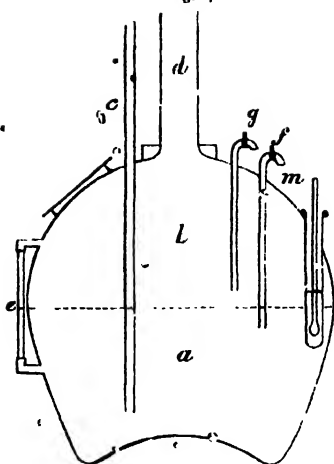
but water, its extremity being un-
der water, while from *g* steam
alone should come away. If water
come from both, the boiler is too
full; if steam alone appear on
opening each, there is too little wa-
ter; *e* is a glass tube or gage com-
municating freely with the interior
of the boiler both above and be-
low, in which, where it can be con-
veniently applied, the actual level
of the water within the boiler is
indicated by its height within the
tube. Immediately above *e* is a
large opening or door, such as is
usually attached to boilers, and by
which access can be obtained to the interior of the boiler, to
clean it or repair it; *m* is a thermometer placed in an iron tube
containing mercury, and indicating the temperature of the wa-
ter in the boiler.

113. Fig. 58 represents the safety valve loaded with a very

Fig. 58.

large weight. A great variety of
forms are given to it according to
the position in which it is to be
placed, and the amount of pressure
to which it is likely to be subjected.
It consists essentially, as is repre-
sented in the figure, of a plate of
metal covering an aperture in the
boiler, and loaded with such a weight
only as will admit of its being forced
up by the steam within, before it at-
tain sufficient power to burst the
boiler. The steam, after escaping
from the boiler by the valve, in ge-
neral passes into a tube which leads it away to the chimney or
a small funnel by which it passes into the air.
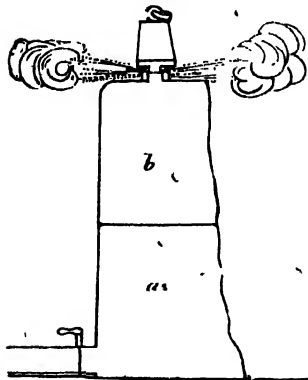
114. At the bottom of this figure (58) a large valve is repre-
sented, which is opened from time to time in boilers worked
with sea water, and a quantity of the hot water run out. This

carries along with it its own salt and the salt of a considerable portion of the water which has been evaporated, as sea water is far from being saturated with saline matter, and the deposition of salt is thus retarded much, though not altogether prevented. This operation is termed *blowing out*, and is frequently practised in marine engines to prevent the boiler being too quickly covered with a thick crust.

Fig. 59.

115. Fig. 59 illustrates more particularly the manner in which the boiler is supplied with water. So long as the stone float *a* is sustained at a certain height by the water in the boiler with the aid of the weight *b*, attached to the other end of the lever which supports the float, the plug *c* is firmly fixed in its place; but when the level of the water declines, the stone float sinks, depresses its arm of the lever, elevates the other, and the plug *c* is opened; then water passes into the boiler, till it is again arrested by the rising of the float, when the weight *b* pulls down its arm of the lever, and thus closes the feed pipe.
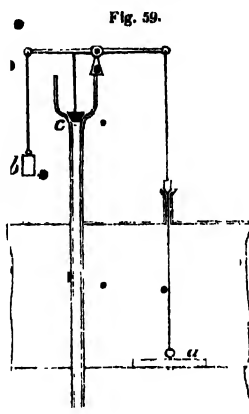
116. The steam gage (Fig. 60) for ascertaining the pressure of the steam is arranged in different ways according to the circumstances in which it is placed. One of the simplest illustrative methods consists in introducing a steam pipe *a* from the boiler into a vessel *b* containing mercury, from which rises a glass tube *c*, dipping under the mercury within this vessel. The more dense the steam the greater its pressing power (or elastic force), and the higher the mercury is forced up in the tube. This apparatus may be attached to the steam pipe (Fig. 57), or it may be connected with the boiler by an independent aperture. Every inch the mercury rises in the tube above the level of that in the vessel, indicates a force in the steam of 0.489 lb. to the square inch
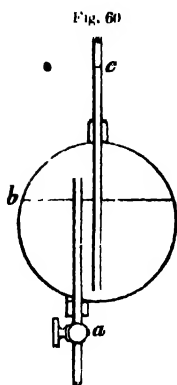
Fig. 60

above the atmospheric pressure ; which is in general 14.6 lb. on the square inch.*

117. Small boilers are occasionally prepared for the same purpose, in which the mercury is placed at the bottom without any intervening vessel, as in the adjoining figure, 61,—b, sur-face of the mercury, d, surface of the water above, a, the tube in which the mercury rises.

Fig. 61.
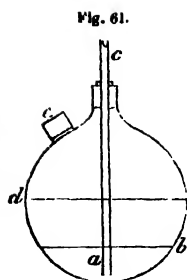
118. All boilers from which much water is evaporated are apt to acquire a thick crust, from the gradual deposition of earthy or saline matter, which often adheres very firmly to the interior of the boiler, and much labour and expense are required for its removal. It intercepts the heat to a great extent, and renders the boiler apt to become red-hot, and more readily corroded. Hence the great advantage of using distilled water for forming the steam, condensing it with-out mixing with other water (by exposure to cold surfaces), and returning it to the boiler, so as to afford a constant supply of a pure fluid that does not communicate a crust to the boiler. This is done in Howard's vapour-engine, and in Hall's patent con-denser. The small quantity lost by leakage is supplied by a small still (in which salt water is distilled.)

119. A mixture of bran and water, or water mingled with various mucilaginous substances, prevents any earthy deposit from concreting so quickly into a hard mass, and attaching itself to the boiler, subsiding then in a form in which it is re-moved with greater facility from the boiler. The objection to the use of all such materials, however, is the extreme tendency which they give to the production of froth, and the consequent danger of boiling over.

120. Fill a long glass flask, with a stout narrow neck, half full of water, boil it till the steam escapes freely, and cork it tightly when boiling, removing it immediately from the heat to which it was previously subjected. The cold air has greater effect in promoting evaporation, by condensing the steam within the flask, and relieving the water from its pressure, than in re-tarding its disposition to evaporate, by lowering its temperature. Ebullition accordingly takes place with rapidity, and even con-tinues for a considerable time.

* See the Tables on the Force of Vapour, &c.

121. If the flask be now plunged into cold water, this fluid acting more effectually than the air, the ebullition proceeds more actively than before. If, on the other hand, it be transferred to boiling water, the ebullition is instantly arrested, because the hot water sustains the vapour in the interior of the flask, pressing on the water, and resisting its ebullition. Lastly, if it be again transferred to cold water, and the cork withdrawn while the liquid is boiling briskly, the air, now gaining admission to the interior, presses upon the surface of the water, and prevents all farther ebullition.

122. Take the same flask, with about a sixth part of water. Boil it, and cork the flask when the air has been expelled as before (120); leave it to cool with the mouth under water, as in

Fig. 62.
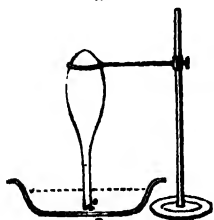
the annexed Figure ; and then, after removing the retort stand, hold it firmly in one hand with its mouth under the water, and remove the cork by the other. The watery vapour being already condensed, the moment the cork is removed, the pressure of the air forces the water with explosive rapidity into the flask. On several occasions I have seen the flask broken by the sudden impetus of the water.

123. The sudden condensation of water or other vapour cannot be too cautiously guarded against in numerous chemical experiments, proving often a source of accident and danger to the inexperienced operator. Where the beak of a retort producing vapour terminates in a receiver, in which it is gradually enveloped in the condensed liquid, if the receiver be kept cool, the material condensed may be returned, by the pressure of

Fig. 63.
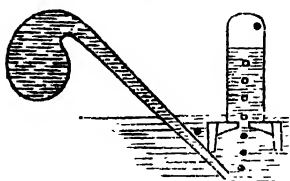
the air, to the body of the retort. Again, if a retort be employed for the production of gas where a condensible vapour is necessarily formed at the same time, if the last portions of gas shall have been expelled, the pressure of the air may force part of the water in the trough into the retort, Fig. 63, and injure the materials there, or break it with explosive violence.

124. The WATER-HAMMER, Fig. 64, shews well the facility

Fig. 64. with which vaporization may be induced when the pressure of the atmosphere has been removed. It con-sists of a glass tube, with hollow balls of different sizes attached to one end, and communicating with the tube by narrow apertures. Water is introduced into it, and when the air has been expelled by boiling, the extremity is sealed hermetically: If it be held so that the water shall fall quickly from the upper extremity of the long tube to the other, as represented in the Figure, a loud noise is produced, the water meeting with little or no resistance in its descent. If, again, the greater portion of the water be transferred to the balls, and the tubular portion be held in a warm hand, the heat of the hand is sufficient to cause it to enter into ebullition, the vapour condensing in the cooler liquid in the ball.

125. The PULSE-GLASS, Fig. 65, consists of two hollow balls, each partially filled with spirit of wine, the air having been entirely expelled, as in the preceding case, by ebullition. If the ball *b* be held in the hand, the spirit boils violently, and is transferred, by the force of its own vapour, to *a*, and may be sent back again to *b* by holding *a*. Great variety of effect is produced by diffe-rent individuals, according to the temperature of the hand. With some persons the hand is generally so cold, that no ebulli-tion is induced.

Fig. 65.

126. The CRYOPHORUS, Fig. 66, is a larger glass vessel than the pulse-glass ; it is charged with water instead of spirit of wine, and prepared in the same manner, the water being boiled to expel the air, after which it is sealed hermeti-cally. All the water having been transferred to one of the balls *a*, the other is placed in a basin or trough, and a freezing mix-ture of salt and snow,* which acts more speedily if previously allowed to liquefy, poured upon it. The vapour within the ball surrounded by the freezing mixture is rapidly condensed, fresh

Fig. 66.

* See freezing mixtures. Any other mixture of equal power may be sub-stituted.

vapour rises from the water in *a,* and it loses so much heat in this manner by evaporation, that it speedily freezes. When the balls are four or more inches in diameter, the water at the surface often freezes before the whole of the mixture has been poured into the basin. When part of the water has been frozen, the ball in the freezing mixture may be removed. This beautiful apparatus was invented by Dr Wollaston.

127. From the large quantity of caloric which becomes latent when water is converted into steam (as much as would raise its temperature 1000 degrees according to some estimates, and 950 or 967 according to others), and which is evolved again when it is condensed, steam is often employed to communicate heat, as in the distillation of alcohol or ether, in drying precipitates, &c. In distilling liquids according to this plan, a pipe from a still in which steam is produced is coiled round in another still containing the liquid to be heated, and by placing this still (where the steam is condensed) on a higher or lower level than the first still, it may be made either to return to the first still, where it would be again converted into steam, or collected and used as distilled water.

128. For drying precipitates, a square box of tinned iron

Fig. 67.
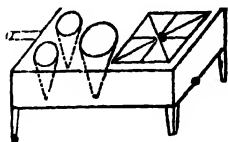
Fig. 67, will be found very convenient, which may be heated by a pipe conveying steam from the small still represented by Fig. 53, page 33. It may be made about twelve or sixteen inches long, from eight to twelve broad, and about six inches deep. The condensed steam is conveyed away by a spout placed at the bottom, and opposite to the end where the steam is introduced, and the box has a slight inclination, so that the liquid may easily run off. In addition to a flat surface for laying any substance on that is to be speedily dried, (as a filter with a precipitate, see the figure,) it is convenient to have one or two funnel-shaped

Fig. 68
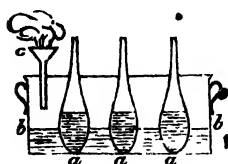
cavities of different sizes passing through it, to hold filters containing liquids that must be kept warm during filtration. These are represented by the dotted lines, and are open both above and below, like a common funnel. Fig. 68 shews a very simple method of converting any ordinary

pan or boiler into a water bath, which may be fitted up for one or more flasks, according to its size. The lid is provided with apertures for the flasks, and water is poured from time to time through the funnel.

129. In studying numerous processes in which water is produced or decomposed, the beginner will derive much assistance from a careful examination of the following propositions: I. When water is decomposed by a metallic sulphuret or chloride, the hydrogen almost invariably goes to the sulphur or chlorine, forming hydrosulphuric acid or hydrochloric acid, while the metal takes the oxygen and is converted into an oxide, which remains in combination with the acid. A similar action ensues when bromine, iodine, or cyanogen, in combination with a metal, decomposes water. If two equivalents of any of these substances should be united with one of the metal, as in the bicyanide of mercury, then two equivalents of water are decomposed, the two of hydrogen in the water going to the two of cyanogen in the bicyanide, and forming two equivalents of hydrocyanic acid, while the corresponding equivalents of oxygen combine with the mercury, and convert it into a binoxide.

130. II. Again, when a compound of a metallic oxide with an acid, such as the hydrochloric or hydrocyanic, is decomposed (hydrochloric acid consisting of chlorine and hydrogen, and hydrocyanic acid of cyanogen and hydrogen), the oxygen of the oxide unites with the hydrogen of the acid, and water is reproduced, while the other substances combine ; viz. the chlorine or cyanogen and the metal. Nothing can be of more importance than acquiring a clear and precise idea of the nature of these changes, as they are constantly taking place in a great number of combinations and decompositions.

SECT. II.—BINOXIDE OF HYDROGEN, OR OXYGENATED WATER.

Symb. H^2O or :H ; Eq. by W. 17; Spec. grav. 1.452.

131. It will be unnecessary to describe minutely the manner of preparing this compound, as from the complicated nature of

the process it is not likely to be the subject of experiment with the beginner ; I shall, therefore, merely mention the method by which Thenard obtained it, and refer to Vols. xiii. and xiv. of the Annals of Philosophy, and to the original memoirs in Vols. viii. ix. and x. of the Annales de Chimie et Physique, where a full detail of all the circumstances to be attended to in preparing it will be found.

132. Hydrochloric acid is diluted with about ten times its bulk of water in a glass vessel surrounded with ice or snow, and the binoxide of barium reduced to fine powder is added in small quantities at a time, as long as any is dissolved. Sulphuric acid is now carefully dropped into the solution to decompose the binoxide of barium, disengaging a portion of oxygen and combining with the oxide (baryta) that remains, forming the insoluble sulphate of baryta which is precipitated. The oxygen combines with a portion of the water, converting it into binoxide of hydrogen, which remains along with the rest of the water and the hydrochloric acid. This is repeated till the water shall have been combined with from twenty to thirty times its bulk of oxygen gas, the hydrochloric acid added to the water at the commencement of the process effecting the solution of the successive portions of the binoxide of barium. Sulphate of silver is employed to remove the hydrochloric acid, the silver being withdrawn by the hydrochloric acid in the form of an insoluble compound ; the sulphuric acid combines at the same time with the binoxide of hydrogen, and is separated by adding powdered baryta.

133. The binoxide of hydrogen prepared in this manner is still diluted with a considerable proportion of water ; it is removed by keeping the liquid in the exhausted receiver of an air-pump with another vessel containing strong sulphuric acid, the water evaporating and being condensed by the acid : care must be taken, however, not to continue the evaporation after the specific gravity of the residue has increased to 1.452, as then the binoxide also begins to evaporate, and mixes with the water and sulphuric acid. (See Air-pump.)

134. The binoxide of hydrogen is distinguished by the great facility with which it is decomposed by most of the metals and many of the metallic oxides, being converted into water and oxygen gas ; with some of the metallic oxides, especially the

oxides of silver, lead, gold, mercury, and platinum, the decomposition takes place the moment they are brought into contact with it; great heat is at the same time produced, and the oxides are reduced to the metallic state, if they belong to the class of metals whose oxides are decomposed by exposure to heat without the addition of any carbonaceous matter.

135. It is decomposed also by heat, being resolved into water and oxygen gas, at the temperature of 59° of Fahr.; and when exposed suddenly to a temperature of 212°, the oxygen is disengaged with explosive violence. When combined with water, or with the stronger acids, it does not part so readily with its oxygen.

It has been proposed to employ it in removing the black specks that paintings frequently acquire from the carbonate of lead originally employed being partly converted into sulphuret by long exposure, when the varnish has been abraded; it immediately converts the black sulphuret into the white sulphate of lead.

CHAP. III.—NITROGEN.

Symb. N. ; *Eq. by W.* 14.2; *by volume* □ (*one measure*). *Sp. gr.* .9785. *Weight of* 100 *cubic inches* 30.346 *grains.* 100 *cubic inches of water absorb about* 1.56 *of nitrogen.*

136. NITROGEN, when uncombined, exists always in the gaseous form, and is distinguished principally by its negative properties, being transparent and colourless, insipid, and inodorous, incombustible, and incapable of supporting combustion. It forms about four-fifths of atmospheric air, exists in almost all the products of the animal kingdom, and enters into a number of important combinations. With oxygen it forms atmospheric air, nitrous and nitric oxides, hyponitrous, nitrous and nitric acids ; with hydrogen it forms ammonia ; with carbon it forms cyanogen ; and it can combine also with sulphur, chlorine and iodine.

137. The best method of preparing nitrogen gas is by burning phosphorus in atmospheric air, included in a jar or bottle over water. For this purpose, a small saucer of tinned iron or a brass stand with a copper cup fixed to the top as represented in

the annexed figure, or any thing that will support a small metal-

Fig. 69.

lic cup with the phosphorus, is placed on the shelf of a pneumatic trough, and covered with a bell jar the moment the phosphorus is kindled by touching it with a small iron-wire previously heated. A large quantity of white fumes is produced, arising from the phosphorus combining with the oxygen of the air, and forming an acid compound, which is diffused through the nitrogen. These are speedily absorbed by the water, and on transferring the residual gas from one jar to another several times under water, nitrogen gas is obtained sufficiently pure for common experiments. It still contains a minute portion of carbonic acid (which is always found in atmospheric air) and a little phosphorus in solution, both of which may be removed, if required, by agitation in a bottle with a solution of caustic potassa.

138. Part of the air included in the jar is expelled, as it is expanded by the heat produced by the burning phosphorus.

139. In experimenting with phosphorus, it may be cut with a knife under water to any size, but should never be touched with the hand when not in this liquid, as it is easily inflamed in the air, sometimes taking fire spontaneously, and giving a severe burn if it come in contact with the hand. It is usually dried by rolling it in bibulous paper.

140. Eight or ten grains of phosphorus may be taken for every 100 cubic inches of atmospheric air, and if a cup fixed to a stand be employed for supporting the phosphorus, it must be raised to a proper height above the water, which rises afterwards in the jar, being forced up by the pressure of the air in place of the oxygen that combines with the phosphorus. Or, a large tin cup may be used, similar to that seen in the next figure, but very flat, and made of thin tinned iron, so that it floats above the ring on which it is at first supported, as the water rises in the jar.

141. It is seldom that any other substance is employed for the preparation of nitrogen. It may be obtained, however, by agitating atmospheric air with a solution of the sulphureted hydro-sulphate of potassa or of lime in a bottle, the oxygen being speedily absorbed while the nitrogen remains. The finger is drawn round the stopple of the bottle with gas lute before it is

introduced, in order that it may be withdrawn more easily.
. When removed it must be taken out under water, a portion of
which is immediately forced in in place of the oxygen that has
been absorbed, and the residual gas may then be transferred to
a pneumatic jar.   See Bi-Sulphureted Hydrogen.

142. A mixture of one part of sulphur with two of iron-filings
speedily attracts oxygen from atmospheric air, if made into a
paste with water, and exposed to a gentle heat before the fire
for two or three minutes, or until it begins to grow warm and,
becomes of a black colour.   It is then put into a tin cup, and a

Fig. 70.
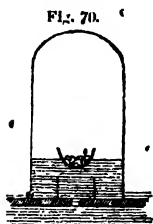
jar of air placed over it on the shelf of the
pneumatic trough, leaving them together for
twenty-four hours, that the oxygen may be
withdrawn. The quantity of sulphuret of iron
used must not be so great as to prevent the tin
cup from floating on the water which ascends
as the oxygen is absorbed ; 300 grains of sul-
phur with 600 of iron and 200 of water will be sufficient for a jar
containing 200 or 300 cubic inches of air, an excess of the mix-
ture being employed to effect a more speedy decomposition.   In
this process, the sulphur and the iron both attract oxygen from
the air, and if they were exposed for a long time to the free
action of the atmospheric air, and properly moistened, they
would be eventually converted into sulphate of iron, the sul-
phuric acid and oxide of iron, formed by the absorption of the
oxygen, combining.

143. In all these processes, four parts by measure of nitrogen
gas are obtained from every five parts of atmospheric air, when
the oxygen has been completely separated.   Nitrogen gas may
be obtained also by exposing muscular fibre to the action of
nitric acid diluted with two or three times its bulk of water ;
see Fibrine.   None of these latter processes, however, are re-
sorted to for the preparation of nitrogen gas, except for experi-
mental illustration, as it is procured with much more facility
by burning phosphorus in air.

144. To shew that this gas cannot support combustion, any
substance may be introduced into it in a state of combustion,
when it will be immediately extinguished.   If two jars are
taken, one full of oxygen, and the other full of nitrogen gas, a
suspended candle, Fig. 9, page 5, introduced into the nitrogen

is immediately extinguished ; but if it have previously been allowed to burn till the wick is red, and the least red spark remain on withdrawing it from the nitrogen, it will be rekindled on transferring it quickly to the jar of oxygen gas, and again extinguished in the nitrogen ; this may be repeated several successive times with the same portions of gas.

145. Mix two measures of nitrogen gas with half a measure of oxygen ; the resulting gas has the same properties as atmospheric air.

146. Nitrogen gas is occasionally employed to fill bottles or retorts instead of atmospheric air, when it is necessary that the gaseous fluid should have no action on the materials afterwards to be introduced.

SECT. I.—OXIDE OF NITROGEN, OR NITROUS OXIDE.

Symb. ON *or* ·N ; *Eq. by* W. 22.2 ; *by volume,* □ *(one measure).*
  Sp. gr. 1.529. *Weight of* 100 *cubic inches* 47.443 *grains.*
  100 *c.i. of Water absorb* 100 *of this gas.*

147. Oxide of nitrogen is obtained by exposing the nitrate of ammonia to heat in a glass retort, when the salt is resolved into watery vapour and oxide of nitrogen, which assumes the gaseous state, and may be collected in a gasometer or in jars placed on a pneumatic trough. To prepare the nitrate of ammonia (composed of nitric acid and ammonia), carbonate of ammonia in powder is added to nitric acid, previously diluted with its own bulk of water, till the acid is neutralized. This is known by taking out a drop of the liquid from time to time with a glass rod, and touching a cabbage test paper with it. See Colouring Matter. Should it be neutral, the paper will not be affected, but is turned green by any excess of carbonate of ammonia, and red by any excess of acid. The nitric acid combines with the ammonia, forming nitrate of ammonia which remains in solution, and the carbonic acid is disengaged with effervescence. The neutralization is effected more speedily by heating diluted nitric acid in a flask, or in an evaporating basin (supported on a retort stand) by a chauffer ; if strong nitric acid be added to the carbonate of ammonia, the nitrate may be

obtained as before, but a large quantity of offensive fumes is disengaged with great violence, and the acid liquid is apt to be thrown about.

148. The solution of nitrate of ammonia thus prepared is heated in a glass retort, of which it should not fill more than a half,—the decomposition of the nitrate commencing when the water of the solution is almost entirely expelled. This is known

Fig. 71.
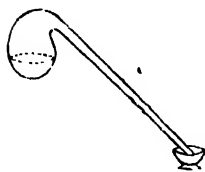
by introducing the beak of the retort into a small cup with cold water, gas rising steadily through it as it is disengaged. Should the decomposition not have commenced, nothing passes over but steam, and the cold water, condensing it, rises in the tube of the retort ; a very small quantity, therefore, must

be put into the cup, to allow atmospheric air to enter by the beak of the retort after the water shall have risen a certain length in the tube, otherwise it will pass into the retort, which will probably be broken. This also shews the necessity of not introducing the beak of the retort into a pneumatic trough or into a gasholder, till the gas begins to be rapidly disengaged. In expelling the last portions of water, great attention must be paid to the management of the heat, as the liquid is then extremely apt to boil over. An iron or tin plate is extremely useful in this stage of the process ; it may be interposed between the chauffer and the retort when the liquid appears as if it were going to boil over, and withdrawn when it falls again in the retort. In this manner the last portions of water are expelled more speedily, and full advantage taken of as high a temperature as can be applied with safety. When the heat to which the nitrate is exposed is too great, the gas that comes away is often impure, and loaded with white vapours of nitrate of ammonia, part of which do not condense for some time, even though shaken with water ; a portion also collects occasionally in a solid mass in the beak of the retort. As the nitrate can be volatilized at a lower temperature than that at which it is decomposed, we must expect that a portion will escape decomposition during the preparation of oxide of nitrogen. When the gas begins to be steadily disengaged, the heat should be moderated, so that the fused nitrate shall be kept in a state of gentle ebullition ; the heat may be continued till the whole of the

nitrate is decomposed. The retort should have a long neck that it may be conveniently introduced into the gasholder, and the beak should not be made so thick as usual, that it may not be so liable to break when it is put into the cold water.

149. Every 54.2 parts or one equivalent of dry nitric acid (contained in 72.2 of the common liquid nitric acid) combine with 17.2 of ammonia, and give 71.4 of dry nitrate of ammonia. This is resolved by the heat into 27 parts of water and 44.4 of oxide of nitrogen, and as 100 cubic inches of this gas weigh 47 grains, 71.4 grains of the nitrate will give about 91 cubic inches of the gas ; of this a large quantity is absorbed by the water of the gasholder or trough.

150. In the following diagram the part to the left represents the elementary composition of the nitric acid and ammonia in 71.4 parts of the nitrate, and the other shews the new arrangement into which these enter, and the compounds produced. The three equivalents of hydrogen in the ammonia combine with three of oxygen from the nitric acid, and the remaining equivalents of oxygen come away with the nitrogen both of the nitric acid and the ammonia, in the form of oxide of nitrogen.

Fig. 72.

| Before Decomposition. | | Products. |

Nitrate of Ammonia = 71.4 grains.	Nitric Acid 54.2	Ox. 8 .... 22.2 Oxide of Nitrogen.
		Ox. 8 .... 22.2 Oxide of Nitrogen.
		Ox. 8.
		Ox. 8.
		Ox. 8.
		Nit. 14.2.
	Amm. 17.2	Nit 14.2
		Hyd. 1 .... 9 Water.
		Hyd. 1 .... 9 Water.
		Hyd. 1 .... 9 Water.

Symb. $: : N + N H^3 = 2 \cdot N \& 3 \cdot H.$
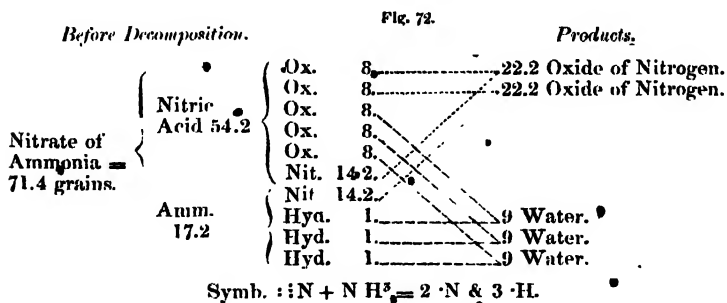
151. Oxide of nitrogen supports combustion more brilliantly than atmospheric air, containing half its bulk of oxygen in a condensed state, whereas air only contains a fifth part of its volume of oxygen.

152. Introduce a suspended candle, Fig. 9, page 5, after the flame has been blown out but with the wick still red, into a jar or bottle filled with this gas ; it kindles into a flame and burns brilliantly.

153. Kindle a wooden match dipped previously in melted

sulphūr, and introduce it into another jar or vase filled with
oxide of nitrogen, having left a little water in to extinguish
any burning sulphur that may drop from it.   The sulphur burns
with a rose-coloured flame.

154. Dry a piece of phosphorus weighing 5 or 6 grains with
blotting paper, and put it in a small copper cup about the size of
Fig. 73. a tea-spoon, supported by a copper wire fixed to a flat piece
of sheet copper, Fig. 73, which should be large enough to
cover the mouth of a jar capable of containing 100 or 120
cubic inches.   On kindling the phosphorus, and introduc-
ing it into the jar filled with oxide of nitrogen, it burns
with great splendour.

155. Charcoal, also, may be burnt in this gas.   Put a few frag-
Fig 74. ments of charcoal into a copper wire cage attached to
a plate of copper by a suspending wire.   Inflame the
charcoal by holding it over a spirit-lamp, then intro-
duce it into a bottle of oxide of nitrogen, Fig. 74.   A
small portion of water should be left in the bottle, in
case any of the hot charcoal should fall out of the cage.
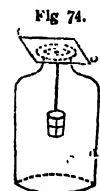
156. Oxide of nitrogen may be detonated with hydrogen by
mixing equal measures in a proper bottle, and applying a lighted
match; the hydrogen combines with the oxygen of the oxide,
and nitrogen gas remains.

157. The characteristic property of this gas is the singular
action which it has upon the animal economy, a high degree of
excitement being produced after a few inspirations, which is
accompanied by a genial glow that pervades the whole frame,
and the most pleasing and thrilling sensations, particularly in
the chest, with a rapid succession of vivid ideas and increased
power and disposition to muscular exertion, which it is impos-
sible for any one to restrain who breathes freely of it.   Out of
nearly 300 gentlemen whom I have seen take it, only four dis-
liked it, complaining of an unpleasant sensation which pervaded
the whole body after they had begun to inspire it, but which
passed away in a minute or two, without leaving any bad effects
or any disagreeable impression.   In another case, the indivi-
dual fainted after six or seven inspirations, but recovered with
a kind of start in a few seconds, without subsequently expe-
riencing any kind of depression.   On a few it had no apparent
effect ; of these, some did not take the gas properly, but one of

them, a South American, took a larger doze three times in succession than any of the others, and breathed with every precaution, after exhausting the lungs as completely as possible of atmospheric air, but still without being in the slightest degree affected by it, a circumstance that attracted our attention more particularly, as it had been lately affirmed in France that the effects which are usually ascribed to it may be traced more to the imagination than to any peculiarity in the gas itself. The others were affected by it in a manner which removed all doubts of the power of this singular gas, even in those who were previously impressed with the idea of the accuracy of the statements made abroad.

158. Occasionally it acted so powerfully on the system that seven people were required to restrain a single individual while under its influence, and prevent him injuring himself or others; ho person, therefore, should breathe freely of it by himself. It is curious, that the excitation which it produces passes away almost as speedily as it is induced, though it occasionally leaves a gaiety and cheerfulness of disposition for hours afterwards; nor is this state of excitation accompanied by any subsequent depression, as is the case with other stimuli, except when it has given rise to violent muscular exertion, when it is always accompanied by a corresponding degree of exhaustion.

159. Another circumstance which I have frequently had an opportunity of verifying is, that the more frequently it is taken the more easily is the system excited by it. In some cases this may indeed be attributed to the gas not being properly inhaled at first, but in many instances which I have seen, different individuals who respired the gas frequently with every precaution were more affected by it on succeeding trials than at first.

160. Different individuals require different quantities of this gas in order to be affected by it, and by varying the quantity the same person generally experiences all the varieties of effect. which it produces, from the most gentle and agreeable stimulus to the most furious excitement, when he will shew a degree of muscular power of which it would scarcely be supposed the human frame was susceptible. In some cases, though the individual cannot restrain himself, he is perfectly conscious of his own actions and of all that is going on around him; in others he recollects nothing from the time a slight giddiness is felt till its effects pass away, when he often recovers with a wild start,

as if unconscious of the place where he is, and those by whom
he is surrounded.

Several gentlemen who not had previously heard of the nature
of this gas, nor were aware at the time of the effect it was likely
to produce while under its influence, stopped suddenly and ex-
claimed, " That they felt as if they were lighter than the atmo-
sphere, and were going upwards," a sensation very often expe-
rienced by those who breathe this gas. .

161. To breathe oxide of nitrogen, an oiled silk bag capable
of containing several quarts must be provided, or a bladder may
be employed if nothing else can be conveniently procured. A
tube is fixed to the bag, and a brass connecting tube fitted to
the other end, in order that it may be attached easily to a gaso-
meter, or any other reservoir from which the gas is obtained.
The tube may be made either of brass, glass, or hard wood.
The latter is preferred, as it is not so liable to do any injury
when the person breathing the gas has been strongly excited by
it, and will not part with it. To prevent the bad effects that
might arise from the too frequent inhalation of the same por-
tion of gas, there ought to be an aperture in the side of the
tube, which may be kept closed by an assistant placing his
thumb upon it (or by a cork) when the bag is filling and dur-
ing the respiration of the gas; by opening it when the respira-
tion of the gas has been continued sufficiently long, and closing
the neck of the bladder at the same time with the finger and
thumb, it is not necessary to force the tube from the
mouth of the person who has been breathing the gas, as
in this manner he will now respire nothing but atmo-
spheric air through the tube. This form of the tube is
represented in the annexed cut.

Fig. 75.

162. Before inspiring the oxide of nitrogen freely, a small
quantity of it should always be tried very cautiously at first, to
ascertain if it be pure. Its taste is sweet and pleasant, and it
has an agreeable though faint odour. If the materials of which
the nitrate of ammonia is made are not pure, the gas is seldom
good, especially if any sulphate or muriate of ammonia should
have been present. When it is to be inspired, the lungs should
be previously emptied as much as possible of common air by a
deep expiration, and the gas inspired and expired into the blad-
der several successive times, the nostrils being held at the same

time by the fingers. The tube should be large enough to allow the gas to pass freely along. When a narrow tube is used, the difficulty of respiration is so great that it seldom produces its characteristic effects.

163. When warm-blooded animals are placed in vessels full of oxide of nitrogen, they die in a short time, and the blood becomes purple; the muscles at the same time lose their irritability; even fishes die in a short time in water impregnated with this gas.

Sect. II.—Binoxide of Nitrogen, Nitric Oxide, or Nitrous Gas.*

Symb. O^2N, *or* :N; *Eq. by W.* 30.2; *by volume* ⊡ *(two measures).* Specific gravity 1.0405. Weight of 100 cubic inches 32.270 grains. Water absorbs from $\frac{1}{10}$th to $\frac{1}{20}$th of its volume of this gas. When mixed with air or oxygen gas, it produces a dense orange-red coloured gas, which is completely absorbed by water.

164. The binoxide of nitrogen is another gaseous compound of nitrogen and oxygen, usually prepared by decomposing nitric acid by means of copper or mercury. For this purpose, put 200 grains of thin copper clippings into a tubulated retort, and pour upon them 600 grains of nitric acid diluted with one and a half times, or twice its bulk of water, the retort being filled about a third full. An effervescence immediately commences, the liquid assumes a greenish-blue colour, and the copper is dissolved; the binoxide of nitrogen disengaged may be collected over the pneumatic trough in the manner represented in Fig. 2, page 3.

By applying heat after the gas has ceased to be disengaged, an additional portion may be procured. Great care must then be taken to prevent the water from rushing into the retort from the pneumatic trough, the watery vapour that passes over being condensed by the cold water; there is no danger of this, however, as long as the binoxide is steadily disengaged, after which

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* Nitrous oxide gas is the name commonly given to the intoxicating gas of Davy.

the beak of the retort may be withdrawn from the pneumatic trough.

Should a more diluted acid be employed, apply heat from the commencement of the process. The solution of the nitrate of copper that remains in the retort may be reserved for future experiments.

165. In this process, every three eqs. of copper decompose one eq. of nitric acid, combining with three eqs. of the oxygen, and being converted into three eqs. of the oxide of copper. Each of these eqs. of oxide of copper unites at the same time with one eq. of nitric acid, forms nitrate of copper, and remains in solution. The nitrogen of the eq. of nitric acid which is decomposed comes away with the remaining oxygen in the form of binoxide of nitrogen. The following diagram conveys a more precise idea of the manner in which the copper reacts upon the nitric acid which is decomposed, the part to the left expressing the materials used, while the other shews the manner in which they arrange themselves.

Fig. 76.

	Binoxide of Nitrogen,	32.2	----- 32.2 Binoxide of Nitrogen.
4 eqs. of Nitric Acid 216.8.	Oxygen, ...	8.0.	
	Oxygen, ...	8.0.	
	Oxygen, ...	8.0.	
	Nitric Acid,	54.2.	
	Nitric Acid,	54.2.	
	Nitric Acid,	54.2.	
3 eqs. of Copper 95.1	Copper, ...	31.7.	93.9 Nitrate of Copper.
	Copper, ...	31.7.	93.9 Nitrate of Copper.
	Copper, ...	31.7.	93.9 Nitrate of Copper.

Symb. 4 ∷ N & 3 Cu = : N & 3 [∷ N·Cu.]
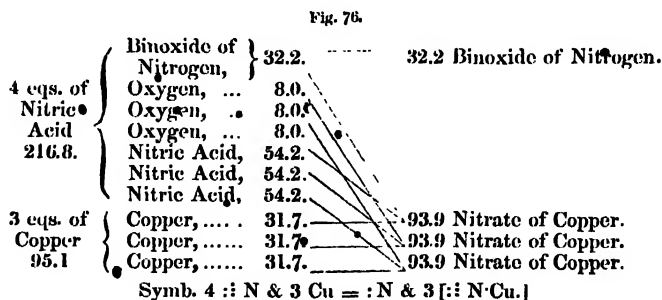
166. When mercury is used for the preparation of this gas, equal weights of this metal and nitric acid are employed, diluting it with water as before, and applying heat from the beginning. In other respects the process is conducted in the same manner as when copper is used, and the same precautions taken as the last portions of gas are disengaged. The theory of the process is also similar, the mercury being oxidated by part of the acid from which the binoxide is evolved, and combining with another portion of acid which is not decomposed, and retains it in solution.

167. Binoxide of nitrogen is a transparent and colourless gas, easily distinguished from all other substances by the dense orange-red and suffocating vapours that are produced when it is brought into contact with oxygen gas or atmospheric air. It does not support the combustion of all inflammable substances, burning sulphur and a lighted candle, for example, being immediately extinguished in it, while phosphorus burns with greater brilliancy than usual if introduced into it in a state of active combustion.

168. To see some of the peculiarities of this gas in regard to inflammable bodies, a suspended candle or a sulphur-match may be introduced into a jar of binoxide of nitrogen in the usual manner. Phosphorus, again, must be allowed to burn a few seconds in the open air before it is introduced, otherwise it also will be extinguished ; it may be supported in the manner described in 154, page 50.

169. Hydrogen does not detonate with this gas when they are mixed together and exposed to heat, but burns away with a quick though silent flame, of a white colour tinged with blue. Equal measures of the gases may be mixed together for this purpose in a long glass jar, and a lighted match applied to the mixture.

170. When oxygen gas and the binoxide of nitrogen are mixed together, the proportions in which they react upon one another, and the nature of the resulting compound, are modified by a variety of circumstances. Three different compounds, viz. hyponitrous, nitrous, and nitric acids, are formed in various proportions, according to the relative quantities of the gases, the size and shape of the vessel in which the mixture is made, the nature of the fluid over which they are mixed, the time they are left in contact with each other, and other circumstances of less importance.

171. When an excess of the binoxide is mixed with oxygen over mercury, in a tube containing a solution of caustic potassa, every half measure of oxygen (one equivalent) combines with two measures of binoxide of nitrogen (one equivalent) ; and they are completely absorbed by the solution, hyponitrous acid being formed, which remains in combination with the potassa. This is the smallest proportion of oxygen with which binoxide of nitrogen can combine.

172. When two measures of binoxide of nitrogen (one equivalent) are mixed with one measure of oxygen (two equivalents) in a wide jar over water, a complete condensation ensues; all the oxygen combines with the binoxide and forms nitrous acid vapour, which is speedily absorbed by the water.

173. Both these compounds (nitrous and hyponitrous acids) are formed when equal bulks of atmospheric air and binoxide of nitrogen are mixed together in a wide jar. Two equivalents of oxygen combining with one of the binoxide form nitrous acid, which is immediately condensed, while other two equivalents of oxygen combine each with one equivalent of the binoxide, forming two equivalents of hyponitrous acid, which are also condensed. Hence, as the oxygen reacts on three times its bulk of the binoxide, and a complete condensation takes place, on dividing the amount of the condensation by four, the product expresses the quantity of oxygen present in a given bulk of air. It must be particularly noticed, in calculating quantities in this experiment, that when equal bulks of air and binoxide of nitrogen react in the preceding manner, one-fifth of the binoxide remains unconsumed.

174. Gay Lussac has found that the quantity of oxygen in mixed gases may be determined in the same manner, whether there shall be a larger or smaller proportion of oxygen present than exists in atmospheric air, if care be taken always to have a sufficient quantity of binoxide of nitrogen present; the condensation being always uniform when the binoxide is added at once to the oxygen in a wide vessel. When a narrow tube is employed for mixing the gases, the condensation is not uniform, and the resulting compounds are so slowly absorbed, that it is necessary to agitate them with the water, when a portion of the binoxide is at the same time absorbed.

175. These experiments may be made by mixing air and oxygen with different proportions of binoxide of nitrogen in glass jars over the pneumatic trough, taking a small jar to measure the different quantities. Any excess of the binoxide may be easily detected, by mixing a little air or oxygen with the gas in the jar suspected to contain it. If, on the other hand, all the oxygen should not have been consumed, on introducing a little binoxide of nitrogen, ruddy vapours will be immediately produced; hence, binoxide of nitrogen and oxygen gas may be

employed, each to indicate the presence of the other ; and by adding an excess of one to any gaseous mixture containing the other, it may be entirely removed, as the compounds which they form are so readily absorbed by water.

176. If binoxide of nitrogen be made to pass through a solution of the green muriate or sulphate of iron, a large quantity of this gas is absorbed ; and the liquid becomes quite black and opaque when fully saturated with it. This solution was employed by Sir H. Davy for ascertaining the quantity of oxygen in any gaseous mixture, as it absorbs it quickly ; it is not much relied on now, however, as an evolution of the binoxide usually accompanies, or at least speedily follows, the absorption of the oxygen gas. The change in the appearance of the solution of the sulphate of iron, and the absorption of the binoxide of nitrogen, may be easily shewn by introducing the beak of a retort from which this gas is escaping, under the surface of the liquid placed in a glass vessel.

SECT. III.—HYPONITROUS ACID.

Symb. O³N, *or* :N ; *Eq. by W.* 38.2.

177. Hyponitrous acid may be formed in combination with potassa in the manner described in 171, page 55. It has also been procured by mixing half a measure of dry oxygen (one eq.) with two measures of the binoxide of nitrogen, and exposing the orange mixture thus obtained to great cold. It is colourless at 0°, but green at common temperatures, and produces much vapour on exposure to the air. Mixed with water, 3 eqs. produce 2 of binoxide of nitrogen and 1 of nitric acid. But if mixed with nitric acid, nitrous acid is produced.

Symb. 3 :N = 2 :N & ::N, — :N & ::N = 2 ·:N·

SECT. IV.—NITROUS ACID.

Symb. O⁴N, *or* ·:N ; *Eq. by W.* 46.2 (O. 32 + 14.2 N.) ; *by volume* □ *(one measure).* *Sp. gr. of liquid acid* 1.452 ; *boils at* 82°. *Its vapour is of a deep orange-red colour, and rapidly absorbed by water. Sp. gr.* 3.183. *W. of* 100 *c. i.* 98.733 *grains.*

178. This is the compound that has been so frequently

alluded.to in Sect. II., and which is formed so abundantly when binoxide of nitrogen is mixed with air or oxygen.

To prepare it in the liquid state, dry nitrate of lead is exposed to a dull red heat in a green glass-retort placed in a sand-bath (see the succeeding section), condensing the vapours that are disengaged in a receiver kept cold by a freezing mixture of ice and salt; the heat may be continued till there is no farther condensation of liquid in the receiver. The nitric acid is completely decomposed; the nitrous acid condenses in the form of an orange-red coloured fuming liquid; and the oxidated metal remains in the retort.

179. Liquid nitrous acid evaporates speedily when exposed to the air, forming a highly corrosive and suffocating vapour, which can support the combustion of a taper or of phosphorus; while other substances, as sulphur, are extinguished in it, though introduced in a state of active inflammation. It is extremely acrid and corrosive of animal and vegetable matter, and reddens vegetable blue.

180. Add a large quantity of water to nitrous acid; part is converted into nitric acid, which remains in combination with the water, forming a colourless solution, and part into binoxide of nitrogen, which escapes with effervescence.

181. Add a smaller quantity of water to nitrous acid, and then gradually increase the proportion of water, till a colourless solution is obtained. It passes through a variety of shades of colour, from a deep reddish-brown to a greenish-blue, hyponitrous and nitric acids being formed in various proportions.

182. Nitrous acid is seldom prepared, except for experimental illustration. It is produced in numerous experiments by the decomposition of nitric acid, and is often employed in combination with it. Should it be required to shew this compound in the gaseous state, when prepared by the action of oxygen and binoxide of nitrogen gases, the experiment must be conducted in the following manner, as it cannot be kept over water or mercury, the former condensing and the latter decomposing it.

183. Dry some oxygen and binoxide of nitrogen gases, by placing them in jars over mercury, with fragments of chloride of calcium. Then fill *half full* with the dry oxygen, a stout glass-jar provided with a stopcock, similar to that represented by Fig. 46, page 28, in connection with the bladder apparatus,

and capable of containing about 20 or 40 cubic inches., Connect with it a flask also provided with a stopcock, and previously exhausted by the air-pump ; on depressing the jar in the mercury, and opening the communicating stopcocks, all the oxygen is forced into the flask by the pressure of the air. The stopcocks being shut, the jar replaced on the shelf of the mercurial trough, and *filled* with dry binoxide of nitrogen, it is introduced into the flask in the same manner as the oxygen, producing dense ruddy vapours of nitrous acid as they mingle together. The stopcocks may then be shut, and the flask removed from the jar. In measuring the oxygen and binoxide of nitrogen, the precautions mentioned in 92, page 30, must be attended to.

Sect. V.—Aqueous Nitric Acid.

Dry Nitric Acid, Symb. O^5N, *or* $::N$; *Eq. by W.* 54·2 (O. 40 + 14·2 N). *Strongest Aqueous Nitric Acid, Symb.* $3·H + 2 ::N.$; *Eq. by W.* 135.4. *Sp. gr.* 1.5. *Aqueous Nitric Acid, sp. gr.* 1·18, *Eq. by. W.* 72·2, *consists of dry Nitric Acid,* 54·2 + 18 *water.* *Transparent and colourless, but soon acquires a straw colour on exposure to light ; emits suffocating fumes, when exposed to the air, and absorbs water. Extremely acid and caustic*

184. Nitric acid has not hitherto been obtained in an insulated form, and the term is usually applied to a compound of the dry acid with two equivalents water. In this state it is sometimes termed liquid nitric acid, hydro-nitric, or aqueous nitric acid, to distinguish it from the dry acid.

185. To prepare this acid, 101.4 parts of bruised nitrate of potassa are put into a plain or tubulated retort, and exposed to heat with 98.2 of sulphuric acid, the product being condensed in a glass receiver, When a plain retort is employed, the sulphuric acid must not be poured down the neck, but introduced into the body of the retort by a long funnel, Fig. 53, page 34, as any that might remain in the neck of the retort would be carried over with the nitric acid in the subsequent stages of the operation, and render the product impure. The retort is then

Fig. 77.
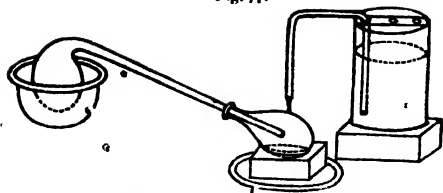
placed in a sand-bath, consisting of an iron basin with a little sand in it, the lower part resting about an inch above the bottom of the basin. When it has been properly adjusted, and the beak introduced into a receiver, more sand is poured in till the iron-basin shall have been completely filled. The body of the retort may be covered to a greater height with sand, by placing round it a ring of thin sheet-iron, from one to two inches deep, a small piece being cut out on one side to allow the neck of the retort to be inclined in the manner shewn in the figure. The retort should be of such a size as to allow at least half an inch of sand between it and the sides of the iron-basin, otherwise it is very apt to be broken when the heat is raised.

The iron basin is heated by the furnace used for the preparation of oxygen gas, Fig. 11, page 7, to which it is adapted, the flange on the outside of the basin resting on the upper part of the furnace, while the lower part is freely exposed to the action of the fire. The retort is not adjusted till the fire has been kindled, and the iron basin put in its place.

186. The degree of heat is regulated by the plugs or air-holes at the bottom of the furnace, and great care must be taken not to expose the retort to a strong heat at first, as the mixture is then apt to boil over. The acid that is disengaged may be condensed in a receiver covered by a piece of cloth, and kept cold by being placed on a ring of tinned iron, a slender stream of water constantly flowing from a large jar or pitcher through a syphon, in the manner represented in Fig. 77, above. The distillation may be continued till little or no acid is observed dropping into the receiver. It must be kept in a glass bottle with a ground stopple.

187. Light green glass retorts do better for this distillation than flint-glass retorts, and should always be preferred when they can be procured, as they are not so liable to be broken. Instead of heating the retort by a sand-bath, the operation may be conducted much more expeditiously on the small scale by means of a chauffer or lamp; constant attention, however, will be neces-

sary in this case to regulate the fire, as it is not so easy in this manner to maintain a uniform temperature.

188. The distillation may also be conducted in flasks with a long glass-tube bent at one end in the manner shewn in the an-

Fig. 78.

nexed figure, the condensation of the acid being effected almost entirely in the tube. This is a very convenient method of conducting the process, and is often preferred to distilling the nitric acid from a retort, though beginners find some difficulty in adjusting the tube. The nitre and the sulphuric acid are first put into the flask, and a thin tube bent at an acute angle about two inches from one extremity, and a very little less in diameter than the neck of the flask, is surrounded with some well worked clay, and put into it. The acid is collected in a receiver, into which the other extremity of the tube is introduced.
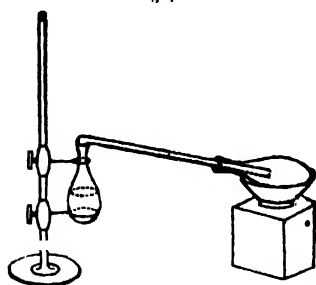
189. The following diagram represents the action that takes place. Every two equivalents of the common sulphuric acid (98.2) consist of two equivalents of water (18) and two of dry sulphuric acid (80.2) ; the nitrate of potassa, on the other hand, is composed of one equivalent of potassa (47.2) and one of nitric acid (54.2). The dry sulphuric acid combines with the potassa, forming bisulphate of potassa, and the water goes to the nitric acid, forming with it the vapour which is condensed in the receiver, dry nitric acid not having hitherto been procured in a free state, as it is always decomposed when disengaged from any of its compounds if no water be present to condense it.

Fig. 79.

Materials decomposed.			Products.
	Water	9.	72.2 Aqueous Nitric Acid.
98.2 Aqueous Sulphuric Acid,..	Water	9.	
	Dry Acid	40.1	
	Dry Acid	40.1	
Nitrate of Potassa 101.4	Nitric Acid 54.2		
	Potash	47.2	127.4 Bisulphate of Potassa.

Symb. 2 ($\cdot$H + $\cdot$S) & :¦N $\cdot$K = 2 $\cdot$H + :¦N & 2 ¦S + $\cdot$K.

190. This is the explanation of the action according to Dr

Wollaston and Dr Thomson's first views, and till lately generally adopted. Dr Thomson, however, in his Inorganic Chemistry, remarks, " when 12.75 parts of nitre are exposed to heat in a retort with 12.25 of the sulphuric acid of commerce, the specific gravity of the acid that is usually procured is 1.4855." He also remarks that, " by regulating the temperature cautiously, the nitric acid procured, consists of one equivalent of acid and one of water, the other equivalent of water remaining in the retort with the potassa and sulphuric acid. In general, however, a little more than half of the water comes over with the acid, in consequence of the heat to which the materials are exposed, and accordingly the specific gravity of the acid obtained must also vary in proportion to the water combined with it."

Mr Philips, on the other hand, affirms that when two eqs. of nitre, four of sulphuric acid, and five of water are carefully heated, the products are

108.4 Nitric Acid + 27 Water, and 254.8 Bisulphate of Potassa + 18 Water.

Symb. 2 (::N + ·K), & 4 :S + 5 ·H = 2 ::N + 3 ·H & 2 (2 :S + ·K) + 2 ·H.

These views are confirmed by Mr Graham's researches on salts.

191. A smaller quantity of sulphuric acid is, in general employed for the preparation of nitric acid. The proportions already given are nearly those adopted by the London and Dublin Colleges; the Edinburgh College recommend two parts of sulphuric acid to be taken with three of nitre. One equivalent of sulphuric acid (49.1) is sufficient for decomposing an equivalent of nitre (101.4); but as it only contains one equivalent of water (9), and as the nitric acid in the nitre requires more, a portion of the nitric acid is decomposed, being resolved into nitrous acid and oxygen. When two parts by weight of sulphuric acid are mixed with three of nitre, it is evident that the product will be composed of nitric acid and nitrous acid, and this forms what is usually, though incorrectly, termed nitrous acid. The salt that remains in the retort is in this case a mixture of the sulphate and bisulphate of potassa. The nitric acid that is disengaged at first comes away with the water of the sulphuric acid and is condensed ; towards the end of the process the nitric acid is decomposed as it is separated, a large quantity

of dense red fumes of nitrous acid being disengaged, the most of which are condensed by the nitric acid in the receiver, if it be kept sufficiently cool.

192. On the large scale, glass vessels of considerable size are frequently employed, being placed on beds of sand gradually heated. Iron pots also are sometimes used, as in the annexed figure (80), earthen capitals *a* being adapted to them. The vapour is condensed in large earthen receivers *b, c,* provided with earthen stopcocks, and connected together by an earthenware tube. Another tube *f* leads from the last receiver to a cup or basin, in which it is made to terminate in water, so as to condense any offensive fumes.

Fig. 80.
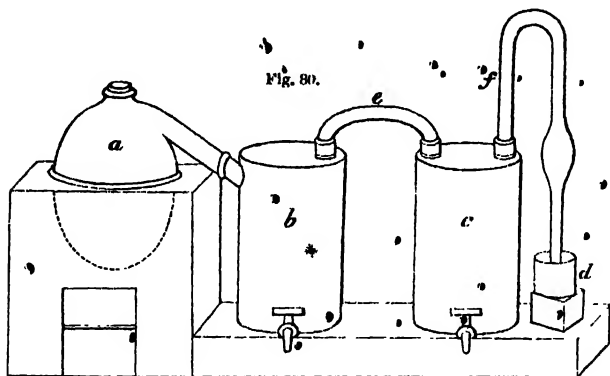
193. In conducting this process on the small scale, 2000 grains of sulphuric acid and 3000 of nitre will be sufficient to shew the difference between the acid procured with this proportion of sulphuric acid, and that obtained when the proportions first given (185) are employed. The retort used may be of such a size that it shall be rather less than half full when both the nitre and the acid have been introduced ; the distillation may be continued till a quantity of acid shall have been obtained equal in measure to the sulphuric acid employed. By continuing the heat still longer, a little more acid may be procured.

194. Nitric acid has usually a slight tinge of yellow, even when prepared from nitre with an equal weight of sulphuric acid, occasioned by the presence of a small quantity of nitrous acid, formed by the decomposition of a minute portion of the nitric acid during its preparation. To deprive it completely of colour, it must be

exposed to heat and boiled, as long as any nitrous acid vapour or binoxide of nitrogen is expelled. When the nitric acid has been prepared with a small quantity of sulphuric acid, it is necessary to expose it to heat for a considerable time before all the nitrous acid is disengaged. By exposure to light also, nitric acid is in part decomposed, oxygen gas being evolved, and nitrous acid formed, which imparts various tints from a light straw colour to a deep orange, according to the quantity produced.

195. It is seldom necessary to expose the mixed acid to heat so as to obtain pure and colourless nitric acid, as it may be used for almost all the purposes to which the latter is applied. It is preferred in some processes from the rapidity with which it acts, being almost always more active than the pale acid met with in commerce.

196. The annexed table by Dr Thomson shews the specific gravity of several compounds of nitric acid and water in atomic proportions, and the quantity of real acid contained in a hundred parts of each. He has calculated that nitric acid composed of 1 atom real acid and 1 atom of water, has a specific gravity of 1.55. But no nitric acid so highly concentrated has hitherto been procured.

Table of Nitric Acid by Dr Thomson.

Specific Gravity.	Acid in 100 parts.	Atoms of Acid.	Atoms of Water.
1.4855	75.000	1	2
1.4546	66.668	1	3
1.4237	60.000	1	4
1.3928	54.545	1	5
1.3692	50.000	1	6
1.3456	46.260	1	7
1.3220	42.857	1	8
1.3032	40.000	1	9
1.2844	37.500	1	10
1.2656	35.294	1	11
1.2495	32.574	1	12
1.2334	31.579	1	13
1.2173	30.000	1	14
1.2012	28.571	1	15

197. The following is a more extensive table by Dr Ure, shewing the quantity of real acid in liquid nitric acid of different specific gravities, which will be found very convenient to refer

to in making experiments where acid of various degrees of strength is required.

Table of Nitric Acid by Dr Ure.

Specific Gravity.	Dry Acid in 100 parts.	Specific Gravity.	Dry Acid in 100 parts.	Specific Gravity.	Dry Acid in 100 parts.
1.5000	79·700	1.3783	52.602	1.1895	26.301
1.4980	78.903	1.3732	51.805	1.1833	25.504
1.4960	78.106	1.3681	51.068	1.1770	24.707
1.4940	77.309	1.3630	50.211	1.1709	23.900
1.4910	76.512	1.3579	49.414	1.1648	23.113
1.4880	75.715	1.3529	48.617	1.1587	22.316
1.4850	74.918	1.3477	47.820	1.1526	21.519
1.4820	74.121	1.3427	47.023	1.1465	20.722
1.4790	73.324	1.3376	46.226	1.1403	19.925
1.4760	72.527	1.3323	45.429	1.1345	19.128
1.4730	71.730	1.3271	44.632	1.1286	18.331
1.4700	70.933	1.3216	43.835	1.1227	17.534
1.4670	70.136	1.3163	43.038	1.1168	16.737
1.4640	69.339	1.3110	42.241	1.1109	15.940
1.4600	68.542	1.3056	41.444	1.1051	15.143
1.4570	67.745	1.3001	40.647	1.0993	14.346
1.4530	66.948	1.2947	39.850	1.0935	13.549
1.4500	66.155	1.2887	39.053	1.0878	12.752
1.4460	65.354	1.2826	38.256	1.0821	11.955
1.4424	64.557	1.2765	37.459	1.0764	11.158
1.4335	63.760	1.2705	36.662	1.0708	10.361
1.4346	62.963	1.2644	35.865	1.0651	9.564
1.4306	62.166	1.2583	35.068	1.0595	8.767
1.4269	61.369	1.2523	34.271	1.0540	7.970
1.4228	60.572	1.2462	33.474	1.0485	7.173
1.4189	59.775	1.2402	32.677	1.0430	6.376
1.4147	58.978	1.2341	31.880	1.0375	5.579
1.4107	58.181	1.2277	31.083	1.0320	4.782
1.4065	57.384	1.2212	30.286	1.0267	3.985
1.4023	56.587	1.2148	29.489	1.0212	3.188
1.3978	55.790	1.2084	28.692	1.0159	2.391
1.3945	54.993	1.2019	27.895	1.0106	1.594
1.3882	54.196	1.1958	27.098	1.0053	0.797
1.3833	53.399				

198. Nitric acid attracts water from the air, and combines with it in all proportions, a considerable condensation attending the combination, which is also accompanied by an evolution of heat. The greatest degree of condensation takes place according to Dr Ure, when 58 parts of acid by weight (spec. grav. 1 500) are mixed with 42 of water, amounting to about one-twelfth of the bulk of the whole ; the temperature rises at the same time about 80 degrees.

199. The *aqua fortis* of commerce is merely a diluted nitric acid prepared by distillation from nitre with diluted sulphuric acid. It contains only one-fourth as much acid, according to Dr Ure, as the strong nitric acid ; what is called double *aqua fortis* contains twice as much acid, being half as strong as the pale nitric acid.

200. The diluted nitric acid of the Edinburgh College consists of equal parts by weight of their strong acid (191) and water ; that of the London College is prepared by mixing one part by measure of acid with nine parts of water ; and the Dublin College employs three parts by measure of acid to four of water.

201. The temperature at which this acid boils varies according to the quantity of water combined with it. When its specific gravity is 1.42, it boils at 248°, and distils unaltered ; nitric acid of this density consists of 1 equivalent of real acid and 4 of water. When its specific gravity is above or below this point, it boils at a lower temperature, and stronger acid becomes weaker, and weaker acid stronger by boiling. Its freezing point varies also according to the quantity of water it contains ; acid of the specific gravity of 1.420 requires a great degree of cold (—41) to congeal it. When poured upon snow it causes it to melt speedily, and an intense degree of cold is produced.

202. If exposed to a red heat in a porcelain tube, it is resolved into oxygen and nitrogen gases, which may be collected at the pneumatic trough. To perform this experiment, a tube about three-fourths of an inch in diameter is stuffed with fragments of earthenware (merely to extend the internal surface), and made to traverse a furnace or large chauffer with a chimney fitted to it. A small tubulated glass-retort is adjusted to one nd, and a bent glass-tube to the other, the joinings being rendered tight with pieces of linen or cotton cloth and the chalk lute ; the extremity of the glass-tube is made to dip under the shelf of the pneumatic trough. The arrangement of the apparatus will be easily understood by referring to Fig. 31, page 20. A small quantity of nitric acid is poured into the retort, and when the porcelain tube is at a full red heat, the acid is made to boil by a small chauffer or spirit-lamp placed below it. The stopple is then put into the retort (not before, lest water should rush from the pneumatic trough into the porcelain tube) and the acid vapours are decomposed as they pass through the

red hot tube, the oxygen and nitrogen gases being collected in jars placed over the trough. The porcelain tube ought not to be exposed to a strong heat at first, but gradually brought to a full red heat, as it is then not so liable to be broken.

203. Nitric acid emits very acrid fumes when exposed to the air; it possesses in a very eminent degree all the characteristic properties of an acid, corroding animal and vegetable substances, reddening the vegetable blues, and forming salts with the different salifiable bases. Its taste is intensely sour and 'acid, even when diluted with a large quantity of water; and it stains the skin of a yellow colour, which remains till the cuticle is completely abraded. It affords oxygen to metals and combustible bodies, many of which decompose it with great rapidity, being usually diluted with water for this purpose, or exposed to heat along with them; all the oxygen, however, is not withdrawn from the nitrogen, binoxide of nitrogen and nitrous acid being generally disengaged during the action that takes place.

204. From these properties, nitric acid is often employed to oxidate a variety of substances. There are several peculiarities in its action, however, more especially when it is of the specific gravity of 1.48, which have not been fully investigated. Thus, antimony has less action with nitric acid of the density of 1.48, than when it is either a little stronger or a little weaker. Tin scarcely affects nitric acid of this strength, but, on adding a little water, a violent reaction takes place. Some singular phenomena connected with the action of nitric acid, more particularly with iron and bismuth, have been investigated lately by Professor Schœnbein, Dr Andrews, and Dr Faraday. It is maintained, that after a wire of iron has been merely dipped in nitric acid of the specific gravity of 1.4, it acquires a peculiar condition, and becomes comparatively *inactive* or *neutral* in this acid. This has been attributed by some authors to a peculiar electric condition, but Dr Faraday considers that it may depend merely upon the metal acquiring a crust of oxide. Metals often take oxygen both from the acid and the water; when this occurs, the hydrogen of the water unites with the nitrogen of the acid, forming ammonia, which combines with part of the nitric acid that is not decomposed, forming nitrate of ammonia; this explains the appearance of the white fumes which are often seen intimately

blended with the nitrous acid vapours that are formed when this
acid is decomposed by a metal having a great affinity for oxygen.

205. If a current of binoxide of nitrogen gas be transmitted
through colourless nitric acid, a large quantity of this gas is
absorbed, and the acid speedily acquires a light straw-colour,
which deepens to a reddish-brown, and passes through various
shades of olive and green, till it at last becomes almost blue.

The apparatus best adapted for this purpose is a
retort or a flask with two tubulures, one for in-
troducing the materials for preparing the bin-
oxide, and the other for a bent glass-tube, which
is accurately fitted to it by grinding, and intended
to conduct the gas to the nitric acid to be im-
pregnated with it ; the acid may be placed in a
common white glass-bottle.

Fig. 81.
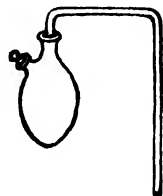
206. An apparatus such as represented by Fig. 82, is fre-
quently used for preparing and transmitting
gases through liquids, when the application
of heat is unnecessary. Should one of this
form be employed on the present occasion,
copper clippings must be put into the bottle
with the long tube funnel, and colourless ni-
tric acid into the other. After adjusting the connecting tubes,
diluted nitric acid is poured upon the copper through the tube-
funnel ; the excess of gas may be collected at the pneumatic
trough.
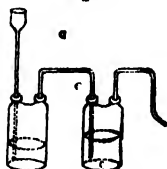
Fig. 82.

207. The change of colour arises from the binoxide of nitro-
gen taking oxygen from the nitric acid, both being converted
into nitrous acid, the one by losing and the other by gaining
oxygen, the depth of colour varying according to the quantity
of binoxide absorbed. Hyponitrous acid is also considered to
be formed, especially as the action advances and the proportion
of binoxide of nitrogen is increased. On exposing the colour-
ed acid to heat, nitrous acid and binoxide of nitrogen are dis-
engaged, and it becomes eventually transparent and colourless.

208. If small quantites of water be added to the strong
fuming acid (composed of nitric and nitrous acids) prepared by
distilling nitre with two-thirds of its weight of sulphuric acid, it
gradually loses its deep orange-red colour, and passes through

various shades of olive, green, and blue. If a larger quantity of water be added, it becomes quite colourless.

209. The nitric acid of commerce is often contaminated with sulphuric and hydrochloric acids, the former arising from the distillation of the acid having been conducted in a careless manner, and the latter, from the nitre employed containing some salts of chlorine. To detect the presence of these acids, the nitric acid must be diluted with three or four parts of water, and solutions of nitrate of baryta and nitrate of silver added to separate portions of the acid in a glass. If any sulphuric acid be present, the nitrate of baryta causes a white precipitate, sulphuric acid always combining with baryta when they meet in solution, and forming an insoluble compound, the sulphate of baryta. Nitrate of silver produces the same effect when hydrochloric acid is present, the chlorine (one of the elements of the hydrochloric acid) combining with the metallic silver, and forming a white curdy precipitate. In applying these tests, it is always necessary to dilute the nitric acid with distilled water, as strong nitric acid, whether pure or not, in many cases gives a precipitate with saturated solutions of salts, the nitric acid combining with the water that retains the salt in solution, while the salt is precipitated in the solid form.

210. The best method of separating sulphuric acid from nitric acid, is to re-distil the acid with an additional quantity of nitre, the sulphuric acid combining with the potassa, and disengaging an equivalent portion of nitric acid. When nitric acid is prepared from sulphuric acid and nitre by a slow fire, using two parts of the acid, by weight, with three of nitre, I have never seen the product contaminated with sulphuric acid.

211. To separate hydrochloric acid, nitrate of silver must be added to it, and the pure acid separated by distillation. It will be found much more convenient when pure nitric acid is required, to examine if the nitre from which it is to be prepared contain any chloride of sodium before distillation, as this is the ingredient that gives rise afterwards to the production of the hydrochloric acid. Its presence is easily ascertained by adding a few drops of a solution of the nitrate of silver to a small quantity of the nitre dissolved in distilled water, a white curdy precipitate appearing immediately, more or less copious, according to the quantity it may contain; the transparency of the

solution is not impaired when the nitre has no common salt mixed with it. (See nitrate of potassa for the method of purifying it from common salt).

212. Nitric acid is easily recognised by the facility with which it is decomposed by iron, zinc, tin, copper, or mercury, ruddy fumes being immediately disengaged. The vegetable alkali morphia has lately been proposed by Dr O'Shaughnessy as a test of nitric acid; a small particle being placed on a piece of paper or card, and touched with a minute drop of the liquid under examination; if it be concentrated nitric acid it instantly becomes yellow, and, in a few seconds, of a fine vermilion red; when the acid is diluted, it may be heated with the morphia in a test tube. Gold leaf is also used to detect nitric acid in solutions containing no chloric nor chromic acids, a few drops of hydrochloric acid being added along with it; if any nitric acid be present, it decomposes the hydrochloric acid, and liberates a portion of chlorine (one of the elements of hydrochloric acid), which dissolves the gold.

213. When the proportion of nitric acid in any solution is extremely small, it will be advantageous to concentrate it by evaporation after neutralizing with potassa, and filtering through paper, should this be required; the potassa prevents any of the nitric acid from being carried away by the watery vapour.

214. Dilute three or four drops of nitric acid with half a dram of water, add a solution of potassa to neutralization, and evaporate that crystals of nitre may be deposited.

215. Fuse a few fragments of the crystals in a glass tube with half a grain of charcoal previously powdered; a deflagration takes place, and carbonate of potassa is left. Dissolve it in water and put a drop of the solution on turmeric paper; it is immediately turned brown.

216. In all cases where the nitric acid is in combination with potassa, or any other salifiable base, as in the example mentioned in paragraph 213, above, an acid (the sulphuric is generally used) must be added to detach it, before any of the tests can indicate its presence.

217. The salts of nitric acid are generally soluble in water, easily decomposed by heat, and deflagrate with inflammable substances. It is easily separated from all its combinations by sulphuric acid, aided by the application of a gentle heat.

218. Nitric acid is much used in the arts. From the facility with which it affords oxygen, it is employed in a great variety of chemical processes, as in the preparation of the nitrates of mercury, tin, copper, and bismuth; for etching on copper; to form *aqua regia* (the solvent of gold) with hydrochloric acid, in the preparation of nitric ether, &c. Diluted with a large quantity of water, it is used internally as a tonic, and occasionally with success, it has been affirmed, in counteracting the consecutive effects of opium. Strong nitric acid is also occasionally employed as an escharotic, and for fumigating apartments and destroying contagious effluvia, as proposed by Dr. Carmichael Smith; for the latter purpose it is disengaged from nitre in the form of vapour, by heating it with sulphuric acid in a cup placed in a ladle containing hot sand.

Sect. VI.—Atmospheric Air.

Eq. by W. 36.4 (Nitrogen, two equivalents, 28.4 + 8 Oxygen). Its specific gravity is reckoned 1, being taken as the standard of comparison in estimating the specific gravity of all other gases. It is about 815 times lighter than water. 100 c. i. weigh 31.0117 grains. Mean pressure in this country = a column of mercury 29.8 inches high, of water 33.72 feet; or = a weight of 14.6 lbs. on the square inch.

219. Scheele's interesting experiment which led more immediately to the discovery of the composition of atmospheric air, may be easily repeated. Pour two ounces of a solution of the sulphureted hydrosulphate of lime (the quadrisulphuret of Dalton) into a bottle capable of containing about twelve ounces, closing it accurately with a glass stopple, and opening it under water after it has been left there for some time. Scheele allowed the bottle to remain for two weeks before he opened it; but if it be frequently agitated, the stopple may be taken out in half an hour, when water will immediately be forced in by the atmospheric pressure in place of the oxygen of the air included in it, the greater part of which will have been absorbed.

220. Introduce a lighted taper suspended by a wire into the remaining gas, viz. nitrogen; it is immediately extinguished.

221. Light a taper supported on a float of wood or tin, place it upon the shelf of the pneumatic trough, and put a glass jar over it.   At first, part of the included air is expelled in consequence of the expansion produced by the heat during combustion; the flame then appears languid, and is soon extinguished, even before the whole of the oxygen is consumed.   Water rises in the jar, being forced up in place of the air expelled at first, and of the oxygen consumed.   Part of the oxygen consumed united with hydrogen from the inflammable matter, producing watery vapour, which condenses on the cold glass.   The remaining portion combines with carbon, and produces carbonic acid gas. which is slowly absorbed by the water.
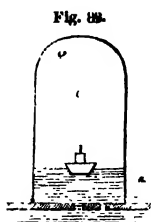
Fig. 88.

222. When the constitution of atmospheric air, and the necessity of the presence of oxygen for supporting respiration and combustion, had been ascertained, many were inclined to attribute the noxious effects of certain states of the atmosphere to a diminution in the proportion of this gas.   The discordance in the results of early experimenters with respect to the quantity of oxygen they found in it, gave some countenance to this opinion; but more accurate researches have since shewn that the proportion of oxygen and nitrogen in the air is the same in all quarters of the globe, and at all elevations to which man has reached.   The *Eudiometer*, now so much employed, derived its origin from this opinion, being an apparatus intended for examining the purity of, or rather the quantity of oxygen in, atmospheric air, but now used also for estimating the proportion of oxygen in mixed gases.   The method of employing binoxide of nitrogen and hydrogen gases for ascertaining the quantity of oxygen in air has been already pointed out.   Volta's and Dr Ure's Eudiometers will be described under Electricity.   Since the discovery of the action of spongy platinum upon mixtures of oxygen and hydrogen, it has been generally employed in ascertaining the amount of oxygen and hydrogen in any gas.

223. A mixture of hydrogen and atmospheric air either does not explode, or at least very imperfectly, unless a particular proportion be observed.   According to Dr Dalton—

Common air and hydrogen in which the oxygen is only $\frac{1}{13}$th, or from six to seven per cent. of the whole mixture, do not explode.

Common air and hydrogen, in which the oxygen is only $\frac{1}{14}$th, or seven per cent., explode imperfectly, leaving both oxygen and hydrogen.

Common air and hydrogen, in which the oxygen is from $\frac{1}{13}$th to $\frac{1}{6.25}$th, or from eight to fourteen or fifteen per cent., fire, leaving hydrogen and azote only.

Common air and hydrogen, in which the hydrogen is $\frac{1}{3.28}$th to $\frac{1}{3}$th, or from fourteen to thirty per cent., fire, and leave oxygen and azote only.

Common air and hydrogen, in which the hydrogen is $\frac{1}{8}$th to $\frac{1}{14}$th, or from eight to twelve per cent., fire imperfectly, and leave oxygen, hydrogen, and azote,

Common air and hydrogen, in which the hydrogen is $\frac{1}{13}$th, or less than seven per cent., do not explode.

When explosion does not ensue, on adding a given portion of oxygen or hydrogen, which must be allowed for afterwards in estimating the proportions, the mixture may be detonated in the usual manner.

224. Phosphorus has also been employed for eudiometrical purposes, a stick of this substance being introduced into the air to be examined in a jar or tube placed on the shelf of the pneumatic trough. The white vapours, formed by the phosphorus combining slowly with the oxygen, are condensed by the water; the nitrogen is left, increased, however, by about $\frac{1}{40}$th part in volume, by combination with a little phosphorus. The phosphorus must be allowed to remain in the jar for a considerable time to withdraw the oxygen completely.

225 Professor Hope's eudiometer, which is represented in the annexed figure, consists of a tube into which the gas to be examined is introduced, about 9 inches long, closed at one end, and ground at the other, so as to fit accurately into the neck of a bottle, which may be 2 or $2\frac{1}{2}$ inches in diameter, and 3 inches deep. It is filled with a solution of the sulphureted hydrosulphate of potassa or lime, placed under water, and the tube with the gas immediately fixed into it under water. It is then taken out of the water and inverted, the gas mixing with the liquid in the bottle, which speedily absorbs the oxygen, when they are briskly shaken together. The stopple in the tubulure, at the lower part of the bottle, should be rubbed over with a little gas lute, and fixed firmly in its place before pouring in the

Fig. 84.
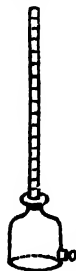
liquid hydrosulphate ; and on taking it out afterwards from time
to time under water, a portion of this liquid is forced in, in place
of the oxygen absorbed ; by observing the height to which it rises
in the tube, which ought to be divided into a hundred parts, the
per-centage of oxygen is ascertained by bare inspection.   The
rapidity with which oxygen is absorbed by the sulphureted so-
lution is influenced much by its strength, and it has been af-
firmed that a small portion of nitrogen is absorbed along with
the oxygen, when water carefully freed from nitrogen by boil-
ing is used in preparing the solution.

226. Atmospheric air always contains a small quantity of
watery vapour and carbonic acid, which may be easily detected
by potassa and lime-water.   The potassa attracts the water and
becomes liquid ; the lime in the lime-water combines with the
carbonic acid and forms an insoluble compound, which collects
as a crust on its surface.   The dry potassa may be placed on a
plate, and the lime-water should be put into a broad shallow
dish, so as to expose an extensive surface to the air.   Besides
these, it must often contain a great variety of other kinds of
volatile matter, though in too small a proportion, in general, to
he rendered sensible by any means of analysis which we at pre-
sent possess.   See Drying of Gases, Ventilation.

227. The chemical agency of atmospheric air depends prin-
cipally, so far as we are acquainted with it, upon the oxygen
which it contains.   It is the oxygen that supports combustion
and respiration ; and, indeed, in all those chemical changes that
are constantly going on at the surface of the earth, in which at-
mospheric air acts an important part, the oxygen has always been
found to contribute to the new arrangements which take place,
while the nitrogen appears seldom to undergo any alteration.

228. The moisture in the air and the carbonic acid come into
play in numerous operations, and the very variable quantity of
watery vapour present in different places and at different sea-
sons affects a number of operations in the arts, which have only
of late years begun to be particularly noticed. ' In summer, the
amount of moisture in the air is much greater than in winter,
which is supposed to be the principal cause of the very inferior
quality of iron which is manufactured in some places where the
season is warmer than in this country, and, in consequence of
which, this process is seldom continued except in the winter
months.

229. Fill a capped receiver *a*, with hydrogen gas. Exhaust the flask *h* of air as much as possible by a syringe, and then join the flask and the receiver by the connector *c*. On opening the communicating stopcocks, the receiver being depressed in the water of the pneumatic trough, part of the hydrogen is transferred to the flask. The receiver should be depressed so that the water shall be at the same level within and without when the flask is charged with gas. This is the manner in which flasks are generally filled with gases, in estimating their specific gravities. Where a mercurial trough can be obtained, it should be preferred in all cases when the gas to be examined has no action with mercury
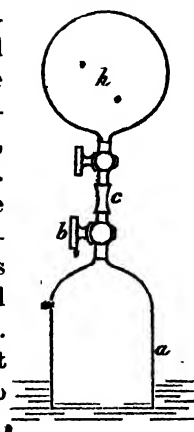
230. A syringe or an air-pump is employed to exhaust flasks, retorts, &c. of atmospheric air. The annexed figures illustrate the manner in which the same syringe may be made to exhaust or compress air, according to the part of it to which the flask is attached. The valves have been placed so as to give an idea of the manner in which they come into play, rather than the actual position they are made to occupy in the syringe itself.

Fig. 85.
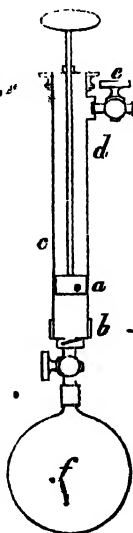
Fig. 86.

Fig. 87.
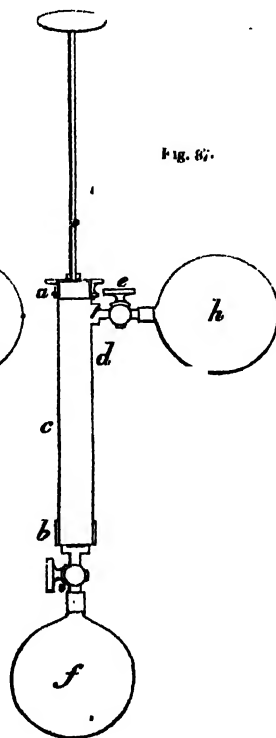
As the piston a, Fig. 86, descends in the barrel $b\,c\,d$, the air be-
tween a and b becomes more and more compressed till it acquires
sufficient density and elastic force to open the valve b, when it is
gradually forced into the flask f, the position of the valve pre-
venting its return.   But the air in the flask h expands when a
void has been formed in the barrel (Fig. 87), and forces open
the valve at the stopcock e; and the air originally included in h
now divides itself between h and the barrel, and when the piston
again descends, the air now in the barrel is transferred as at
first to the flask f.   By continuing to work the syringe, more air
is extracted from h and compressed into f, until the expand-
ing air in f becomes of too weak elastic force to open the
valves.   Even then, however, a still greater degree of exhaus-
tion may be effected by using valves which can be opened and
shut mechanically, as the piston is moved in the barrel.   These,
however, are rarely used, except in the construction of air-
pumps.

231. It will be obvious that the flask h may be exhausted,
though no second flask f be attached to the syringe, the valve b
opening outwards, and permitting the exit, but not the entrance,
of air.   Also, a flask placed where f is represented in the figure
may be charged with compressed air, though none be exhausted,
the valve e permitting the entrance, but not the exit, of any air.

232. Exhaust a flask by the syringe, shut the stopcock, sepa-
rate the flask from the syringe, and open the stopcock under
water; observe the quantity of water which is forced into the
flask by the pressure of the atmosphere.

233. Force air into a flask by the syringe, shut the stopcock,
remove the flask, and open the stopcock under the shelf of the
pneumatic trough, a jar having been placed over it.   The addi-
tional quantity of air forced into the flask will now rush out, and
may be collected in the jar.

234. The extreme elasticity (compressibility and expansibility)
of air and other gaseous fluids continually demands attention in
numerous pneumatic operations, as a very slight change of tem-
perature or pressure causes a comparatively great alteration in
their bulk.   Gaseous bodies increase in bulk on raising their
temperature, or diminishing the pressure upon them; they con-
tract on lowering their temperature (less resistance being then

offered to the pressure by which they are confined), and on increasing the pressure.

235. The air-pump consists essentially of a syringe *a*, which is usually connected by a tube proceeding from the exhausting extremity of the syringe, with a very smooth circular plate of brass on which is placed a glass receiver *b*, ground flat at the edges. To make the connection air-tight, the edge of the receiver is usually besmeared with a little lard, or an extremely thin ring of sheet caoutchouc may be placed upon the plate where the glass receiver rests upon it. Plates of glass or of slate are occasionally substituted for the brass plate. Any materials to be subjected to experiment are placed in vessels within the receiver. The figure shews the position of the valve during the ascending movement of the piston, the air in the receiver expanding during the ascent of the piston, part of it rushes out and opens the valve as it is relieved from superincumbent pressure. During the descent of the piston, the valve prevents the return of the air now in the barrel, which forces open and escapes through a valve in the piston itself. Both valves open outwards.
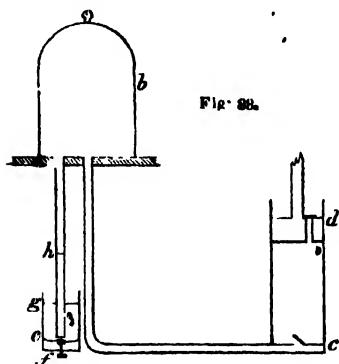
236. To indicate the degree of exhaustion in the receiver, a barometric tube *h* is connected with it, or more frequently with the tube coming directly from it, and is placed so as to dip into a cup of mercury *g e*, a false bottom *e*, made of leather, supporting the mercury, so that the surface of the mercury *g* may be properly adjusted, by turning the screw *f*. The mercury within the tube *h*, and without in the cup, should stand precisely at the same level immediately before commencing any experiment with the air-pump, the mercury rising higher and higher in the tube *h*, the greater the degree of exhaustion. Were the vacuum complete, the mercury would rise to the same height as in the common barometer at the time. The difference shews the force in inches of mercury of the air still in the apparatus (240).

Fig. 89.

237. Fill a stout barometer tube, about forty inches long, and closed at one end with mercury, and insert it in a tumbler of mercury, Fig. 89. The moment the finger or thumb is withdrawn from the open end, the mercury descends about ten inches in the tube. The space thus left void is usually termed a Torricellian vacuum. The mercury descends till the pressure of the remaining part of the column is exactly equal to the pressure of the external air. The mercury within the tube and the air without are each pressing on the mercury in the glass jar, and mutually balancing each other.
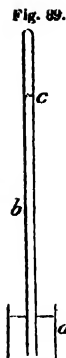
238. The plate of the air-pump is adapted for receiving a great variety of apparatus, and frequently the syringe is attached to a main tube *t f* (Fig. 90), from which a series

Fig. 90.
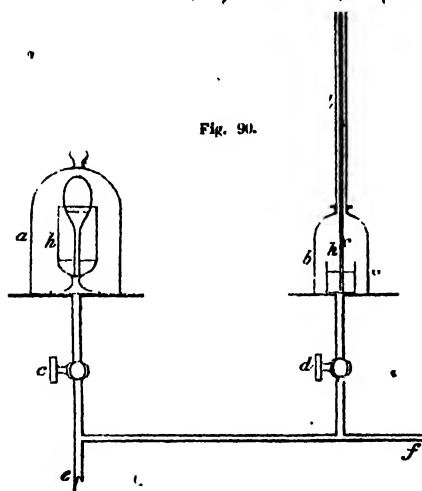
of tubes may be led, each connected with a plate, and each of which can be used singly by opening the proper stopcock *c* or *d*, as the syringe is worked. Any experiment, accordingly, having been commenced, it may be continued with the vacuum already obtained, after the stopcock below the plate has been turned, and a new operation commenced on another plate.

239. Put the long barometer tube and the cup of mercury, as they are represented (Fig. 89), upon the plate of the air-pump. Place over it a capped jar or receiver *b*, Fig. 90, and screw upon it a long tube, so as to include the barometer tube in the manner shewn in the figure by *bkl*.* On working the air-pump, the mercury falls in the barometer tube within the air-pump receiver as the air is exhausted and the pressure diminished upon the surface of the mercury in the cup.

240. The mean force with which the air presses upon the

surface of the earth at the level of the sea is similar to that which would be exerted were the air entirely removed, and a weight of 14.6 pounds avoirdupois, laid upon every square inch of surface, or equal to a column of mercury 29.8 inches, or to a column of water 33.72 feet high. Thus every inch of a column of mercury indicates a pressure of 0.489 lb. avoird. nearly half a pound.

241. As the pressure of the atmosphere is not constant, however, varying in this country nearly to the extent of three inches in the height to which it supports the column of mercury at different times (from 28.1 to 30.8 inches); in all operations with the air-pump, where a precise experiment is to be performed, the pressure of the atmosphere at the time should be ascertained by reference to the common barometer.
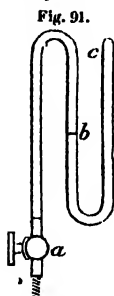
Fig. 91.

242. In experiments where the exhaustion is to be carried to a considerable extent, a small gage, represented in the above figure, 91, is often used. It is screwed into any part of the tube that communicates between the air-pump receiver, and the syringe. When the air remaining in the apparatus becomes of less force than that of the mercury in the vessel c above the level of that in a, the mercury falls in c and rises in a. After that, the difference in level shews the elasticity of the remaining air in inches of mercury. The more nearly the mercury in c and a is on a level, the greater the degree of exhaustion indicated. In no case is the air entirely extracted by the syringe or air-pump from any vessel attached to it.

Fig. 92.

243. Attach a glass tube terminating in a ball to the tube that rises through the air-pump plate (Fig. 92), exhaust it, and shut the stopcock opening it afterwards under water. The pressure of the external air forces water with rapidity into the tube and ball.

244. Place a glass or jar upon the plate of the air-pump; pour a little water into it, and invert a flask half full of water in it, leaving it without any cork or stopple. On working the air-pump, the air in the flask expands, pushes out the water in the

flask, and part may escape from the flask itself, should the exhaustion be continued. On admitting atmospheric air into the receiver again, the thin and attenuated air within the flask cannot resist its pressure, but is reduced to its original dimensions as the water in the jar is forced back into the flask, along with an additional portion that may supply the place of any part of the air that has escaped from the flask.

245. The pressure of the atmosphere is frequently removed in numerous experimental processes and operations of art, by condensing steam in different kinds of apparatus, after it has expelled atmospheric air from the vessel into which it has been introduced. A simple illustration of the principle upon which these processes are conducted may be easily given by boiling water briskly in a flask, corking it tightly when the air has been expelled, and then plunging the flask alternately in cold and boiling water, as in par- 120–1 page 38. In this manner, water may actually be made to boil by placing it in a medium at 60°, which will quickly abstract heat and condense the vapour ; but if the flask be now plunged in boiling water, the ebullition

Fig. 93.

is immediately arrested ; the superincumbent steam is no longer condensed, it presses upon the surface of the water, and opposes ebullition. See Fig. 93.
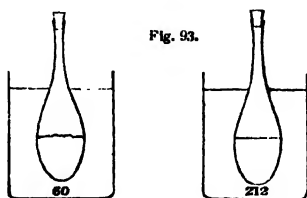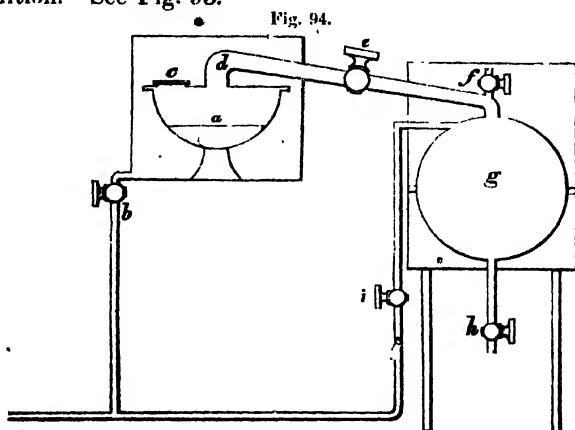
Fig. 94.

246. In Mr Barry's process for inspissating vegetable extracts, distillations in vacuo, &c., the still a (Fig. 94) contains the matter to be distilled, and is carefully luted to prevent any communication between it and the exterior vessel in which it is placed. The receiver g is filled with steam from the pipe attached to it, by opening the stopcock i, the air being expelled by f or h. When f, h, and i are shut, cold water is then made to surround g, and when the steam is condensed, the stopcock e, communicating between a and g, is opened. As, there is a vacuum in g, the air at first in a now divides itself between a and g; the stopcock e is then shut, g filled with steam again, and the air expelled from it. On condensing the steam as before, and opening e, the residual air in a is divided as at first between a and g. This is continued till the vacuum in a and g is considered sufficient; and then, g being kept cold and empty, and all the stopcocks connected with g being shut, except e, steam is introduced into the vessel surrounding a by opening the stopcock b, and the juice evaporated by the heat of the steam. Or warm water may be introduced around the vessel a, and the distillation may be carried on at a very low temperature. Any vegetable juice may thus be inspissated at a temperature so low that there can be no danger of the extract being injured by the heat. In a vacuum liquids boil at about 140° Fahr. below their usual boiling points. Thus if a vegetable juice requires a temperature of 230° to boil it under the atmospheric pressure, it may be boiled at about 90°, by using the above apparatus, and rendering the vacuum very complete. A thermometer may be placed in the liquid a with the stem exterior, so as to indicate the temperature at which the evaporation is going on.

247. In the refining of sugar, the pressure of the atmosphere is removed from the surface of the syrup to be concentrated by an air-pump worked by a steam-engine, and the vapour produced on the application of heat is constantly withdrawn in the same manner. The comparatively low temperature at which the syrup can thus be concentrated, removes the danger of decomposing the sugar, and rendering it more or less brown.

CHAP. IV.—SULPHUR.

Symb. S. *Eq. by W.* 16.1 ; *by volume* .166 *of one measure. Its usual specific gravity is* 1.99 ; *by throwing it when melted, and at a temperature of about* 450°, *into water, it is increased to* 2.325.

248. Sulphur is a solid inflammable substance of a light yellow colour, very brittle, with little or no taste, and emitting a peculiar odour when rubbed. It is an abundant production of the mineral kingdom, and is found chiefly in volcanic countries. It frequently occurs in pyramidal crystals ; and when melted and cooled slowly, it always presents a crystalline structure. Sulphur is also found in combination with a number of the metals, as iron, lead, copper, and antimony ; by exposing the common yellow iron-pyrites (bi-sulphuret of iron) to a red heat in close vessels, it may be procured in considerable quantity ; rising in vapour, which is conducted under water and condensed.

249. When exposed to heat, it melts at the temperature of 216° or 220°, and becomes very thin and fluid at 250°. The roll sulphur of commerce is prepared by pouring melted sulphur into cylindrical moulds ; it gives a crackling noise when held in a warm hand, and often falls to pieces, having little cohesion, and being unequally expanded by heat, as it is a bad conductor of caloric. When exposed to a stronger heat, instead of becoming more thin and fluid, as is generally the case with other liquids, it soon begins to turn thick and viscid, and at the temperature of 450°, the vessel containing it may be inverted without any of the sulphur falling out. By a further increase of temperature it becomes a little more fluid, and if it be then poured into water, it forms a soft and tenacious mass, quite transparent, which assumes the usual appearance of sulphur when kept for some time. All these circumstances may be easily seen by heating sulphur in a dry flask over a chauffer or lamp, supporting it on a retort-stand.

250. To obtain large crystals of sulphur, the best method is to melt one or two pounds in an earthen crucible or large basin,

and invert it after it has been removed from the fire and a crust formed on the surface, a small hole having been made to allow the sulphur that is still liquid to flow out. When the crucible is quite cold, it must be carefully broken, and crystals of sulphur will be found in the interior. On the small scale, melt one or two ounces of sulphur in an evaporating basin, allow it to cool, and when the surface is nearly covered with crystals, pour out as quickly as possible any sulphur that may still be fluid. The sulphur already solidified shews a highly crystalline texture.

251. Dip a conical glass tube into water, and drain off as much as possible, leaving the surface of the glass damp. The neck of a broken retort does very well for this experiment. Place the narrow end in a small mass of clay, allowing it to rest perpendicularly, and supporting the wide end by resting it against the ring of a retort-stand, or by placing it in any other convenient situation. Then pour melted sulphur into the tube, having given it no more heat than was necessary to render it fluid. The sulphur gradually consolidates, and when cold, it may be easily removed by tapping gently the conical tube. On the large scale beechwood moulds are generally used, consisting of two pieces, which are separated when the sulphur is cold.

252. Paste a slip of paper close round the sides of a glass seal, plaster of Paris mould, or any other matrix of some substance not acted on by sulphur, so as to have a rim formed round the edge capable of holding sulphur to the depth of half an inch or more. Pour melted sulphur upon the seal or mould, and allow it to cool. A cast is obtained in this manner with a very accurate impression, which separates in general with great facility when completely cold. By rubbing a little oil on the surface of the mould, and removing the most of it with cotton, before the sulphur is poured upon it, the separation is still more easily effected.

253. Impressions of coins and medals may be taken in the same manner. These are generally taken first in plaster of Paris (see Sulphate of Lime), the sulphur cast being taken subsequently from the plaster of Paris mould. If sulphur be poured directly on the coin prepared in the same manner as is described in the preceding paragraph, a film of sulphur usually

adheres to the coin, which may be removed by rubbing it with a drop of a solution of potassa.

254. Sulphur when newly cast or crystallized is always more or less transparent, but gradually becomes opaque in consequence of the particles assuming a new arrangement, without any chemical change taking place or any alteration in the external form.

255. Sulphur is converted into vapour at 600°, and may be condensed unchanged by conducting the sublimation in vessels where it is protected from the action of the air. This process is generally resorted to for the purpose of purifying sulphur, and when the heat is not too great, the vapour of the sulphur condenses in very minute crystalline grains, forming what is commonly called *Flowers of Sulphur.* To shew the sublimation of sulphur, it may be exposed to heat in a retort with a short neck, connecting it with a large receiver.

256. Sulphur takes fire at about 300° when heated in the open air, burning with a blue flame, and producing very pungent suffocating fumes. In oxygen gas it burns much more vividly and with a larger flame. Sulphurous acid gas is the product of the action in both cases, unless when the gases are moist, a small portion of sulphuric acid then being formed. The apparatus used for the combustion of phosphorus in oxide of nitrogen—Fig. 73, page 50,—may also be employed here. The oxygen neither increases nor diminishes in volume, but its density is doubled, as it takes up an equal weight of sulphur.

257. A thin globe of glass may often be used as a substitute for other apparatus for burning inflammable substances in oxygen. Place a small fragment of sulphur upon a metallic cup, resting the cup upon a wire, which may be fixed in a piece of lead

Fig. 95.
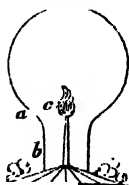
having several grooves in it to admit of the escape of any expanded gas. Inflame the sulphur, and place over it a flask of the form represented in Fig. 95, having previously filled it with oxygen. The flask should be placed upon a tray as near the sulphur as possible, and lifted to its place with the fore-finger and thumb of the right hand, round the stem, till it is properly adjusted.

258. Sulphur is insoluble in water, but combines with it when precipitated from any solution containing it, forming a

white powder, usually called the milk of sulphur. The method of preparing it will be described in the last section of this chapter; it is the precipitated sulphur of the pharmacopœia. Sulphur and alcohol combine when they are presented to each other in the gaseous state. Sulphur is sparingly soluble in ether, but is dissolved readily when boiled in oil of turpentine.

259. Sulphur combines with the metals, forming a great number of very important compounds, and during the combination, light and heat are frequently disengaged; a certain elevation of temperature is almost always necessary, however, to commence the action; and the appearance of the product varies considerably according to the temperature at which it takes place.

SECT. I.—SULPHUROUS ACID.

Symb. O^2S, *or* $:S$. *Eq. by W.* 32.1 ($O. 16 + 16.1 S$); *by volume* □ *(one measure). Sp. gr.* 2.213. *W. of* 100 *c. i.* 68.643 *grains. It is extremely pungent and suffocating. It may be liquefied by a force equal to the pressure of two atmospheres, or by collecting it in small glasses surrounded by a freezing mixture of snow and salt. The specific gravity of the liquid acid is* 1.45; *it boils at* 14° *Fahr., producing great cold. Water absorbs* 33 *times its volume of sulphurous acid gas at natural temperatures.*

260. Sulphurous acid may be obtained by burning sulphur in oxygen gas or atmospheric air; but it is more easily prepared by decomposing sulphuric acid, heating it in a glass retort with some substance which can deprive it of a portion of its oxygen. Almost all vegetable bodies, and a great number of the metals, can produce this effect. Mercury is the metal that is generally employed for the preparation of pure sulphurous acid, two parts of it by weight being mixed with three of sulphuric acid in a tubulated glass retort supported on a retort-stand, heated by a chauffer or spirit-lamp. When it is prepared on the small scale, 200 grains of mercury and 300 of sulphuric acid may be put into a retort capable of containing about three ounces; the beak of the retort should be extremely small.

261. As water absorbs such a large quantity of this gas, it must be collected in jars over the mercurial trough. This

is constructed much in the same manner as the water trough already described, 7, page 3. It may be made of wood, marble, or cast-iron ; the latter is generally preferred, and is well

Fig. 96.
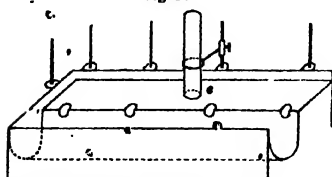
varnished, to prevent it from rusting. The annexed figure gives a view of the mercurial trough I employ, and a section of one of the ends, which will allow its construction to be easily understood. It is 17 inches long, 7 broad, and 5 deep. The mercury does not pass under the shelf, so that the body of the trough is only about half as broad below the shelf as above, and it is rounded at the bottom to save an unnecessary quantity of mercury. There are four niches at the edge of the shelf, at equal distances from one another, to allow the beak of a retort to be introduced more easily under jars placed over them. The small rods attached to two of the sides of the trough are intended for fixing clasps or rings, to steady any tall jar that may be left on the shelf. It requires about 140 pounds of mercury, when a number of jars are used. Newman * has cast-iron mercurial troughs of two different sizes, the one requiring 65, and the other only 20 pounds of mercury ; the large trough allows jars to be used rather more than two inches in diameter, and 9 inches long ; but for the other, they must not exceed 1½ inch in diameter. Almost all the most important and interesting experiments, where a mercurial trough is required, may be performed with a small trough containing only 20 pounds of mercury, and a little practice will soon enable the operator to adjust the beaks of one or two retorts (by heating and drawing them out at the blowpipe) to the small jars or bottles, which he must use along with them.

262. Porcelain mercurial troughs are much employed on the
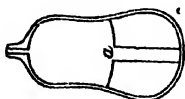
Fig. 97.   Fig 98.   Fig. 99.
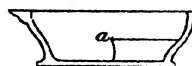
continent, of the form seen in the annexed figures, which shew

* A philosophical instrument-maker in Regent Street, London.

the general construction, and also a longitudinal and a transverse section.

> Length inside at the top, 7 inches.
> Length inside at the bottom, 5½ inches.
> Breadth across *a* at the top, 4 inches.
> Breadth across *a* at the bottom, 2 inches.
> Depth inside, 3 inches.
> Depth of shelf, 1¼ inches.
> At *a* the shelf is deficient, that a tube or jar may be used as long as the
>   trough.*

263. The jars for the mercurial trough must be made at least $\frac{1}{16}$th of an inch in thickness, though not more than 1 or 2 inches in diameter; they ought also to be ground at the edges that they may be removed easily when full of gas on a flat glass plate rubbed over with a little gas-lute, without losing any of their contents. The mercurial trough should be placed in a large sheet-iron tray, several times the size of the trough itself, to prevent any loss of mercury. Bibulous paper is constantly required to remove any acid or water that may collect on the surface of the mercury, and after any acid gas has been prepared over it, the mercury should always be washed with water, and dried with a towel and bibulous paper. A red-hot poker held for a short time in the mercury enables this to be done more effectually; it is in this manner also that mercury is most conveniently brought to a proper temperature when it is required to be heated for particular experiments. The beak of the retort must be placed near the surface of the mercury, that the gas may have to overcome as little resistance as possible in rising through this heavy fluid; should this not be attended to, and the retort be made of very thin glass, it is sometimes broken by the great pressure from within.

264. The theory of the process is very simple; each equivalent of sulphuric acid decomposed (consisting of three of oxygen = 24 + 16.1 of sulphur, one equivalent) loses one equivalent of oxygen (8), which combines with the metallic mercury, and the rest of the oxygen comes away in combination with the sulphur in the form of sulphurous acid gas. The oxidated mercury combines with another portion of sulphuric acid not de-

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* The above is the size of the Berlin porcelain trough generally used. It may be procured at Mr Griffin's establishment in Glasgow.

composed; a bisulphate of the binoxide of mercury is formed when the resulting mass is heated to dryness.

265. The sulphurous acid gas prepared in this manner always contains a small portion of sulphuric acid; and if the heat be urged, and the gas prepared rapidly, the quantity of sulphuric acid carried over is considerably increased. It may be purified in a great measure by passing it through a very small quantity of water, and cooling the tube through which it passes before reaching the mercurial trough. No pure sulphurous acid is obtained till the atmospheric air has been expelled from the retort.

266. To see how readily this gas is absorbed by water, remove one of the jars filled with it by means of a flat glass-plate held firmly to it, or place the thumb or finger on the mouth of a small glass bottle or tube filled with this gas, and take it off under water. This fluid will instantly combine with it, and be forced up into the tube with explosive violence by the pressure of the atmosphere. Should even a very small quantity of air have mixed with it previously, the absorption takes place much less rapidly. A japanned tray of tinned iron, or one of earthenware, of the form represented by Fig. 3, page 4, may be substituted for the glass-plate.

267. Take a small glass-tube, closed at one end, an inch or two long, and about one-third of an inch in diameter; fill it with water, place the thumb upon it, and invert it in the mercurial trough : then transfer a small quantity of water from it into another jar filled with sulphurous acid, in the same manner in which gases are transferred from one jar to another. The mercury will immediately rise in the jar, and the water will be seen to absorb many times its own bulk of this gas.

268. Prepare sulphurous acid gas with 400 grains of mercury and 600 of aqueous sulphuric acid in a small retort; let the beak of the retort be fitted into a tubulated receiver kept cold by ice or snow : let a tube proceed from this receiver and terminate in another, long and narrow, or in a phial of this form. A portion of water and sulphuric acid, with a little sulphurous acid. are condensed in the first receiver ; the second must be kept at zero, or below this temperature, by a freezing mixture of salt and snow, and in it the sulphurous acid gas is condensed into a liquid.

269. Pour a small quantity, about a drachm, of the liquid

bottle must be corked as soon as it is filled, till required for ex-
periment, covering it with a little gas lute if it is intended to
keep it any length of time before using it.

274. To impregnate water with sulphurous acid gas, it must
be passed in a current through this fluid.   The best apparatus
for this purpose consists of a series of bottles connected with a
retort in which the gas is generated, well known by the name of
Woulfe's apparatus. The bottles should be large enough to
contain from twenty to sixty cubic inches, and the connecting
tubes made of very stout glass.   The sulphurous acid gas from
the retort is in part absorbed by the water in the first bottle ;
when the water there is charged, the gas passes from it into the
second bottle by a tube which dips under the water in the second ;

Fig. 101.
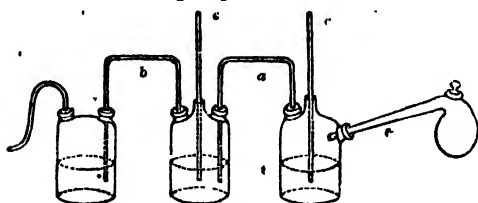
and the excess may
be conducted into
another bottle or
through a series of
them connected with
one another in the
same manner as the
first is connected
with the second.   These tubes, as well as the safety tubes c c
(which will be explained immediately), must all be fitted tightly
to the tubulures of the different bottles, either by passing them
through corks, or having them accurately ground to one another.
A still better method is, to join the connecting tubes to the
tubulures, as Mr Faraday has recommended, by small caoutchouc
tubes or collars, the upper edge being tied round the tube, and
the lower part round the tubulure of the bottle.   The different
bottles then admit of a considerable degree of lateral motion.

275. The long tubes in the bottles c c are termed safety-tubes ;
the manner in which they operate is very simple.   Let us sup-
pose, that a considerable absorption or condensation takes place
suddenly in the bottle connected with the retort, from the sul-
phurous acid ceasing to come before the water has been satu-
rated, from the water combining rapidly with the sulphurous
acid gas, or from the heat applied to the retort having been
withdrawn.   Then the liquid would absorb the gas above it in
the bottle, and were there no safety-tube in this bottle, a portion
of the liquid in the adjoining bottles would immediately rush into

it, being forced through the tubes a, b, by the pressure of the air upon the liquid in the last bottle ; the atmospheric pressure being no longer counterbalanced, in consequence of the condensation in the first bottle ; and the cold liquid thus accumulating in the first bottle, might be forced into the retort. But the safety-tube c (in the bottle next the retort) being open at both ends, it is obvious that the internal pressure may be restored either by air entering through the safety-tube, or by some of the liquid in the second bottle passing into it ; and, as less force is opposed to the air in descending through half an inch of liquid by the safety-tube (the quantity of water generally put into the bottle not being more than sufficient to cover the tube to this depth) than is required to force the fluid from the second bottle through the connecting tube, air continues to pass into it till the equilibrium is restored.

In the same manner, the safety-tube in the middle bottle prevents any of the liquid in the third bottle from passing into it. Should there be no safety-tube in the first bottle, the operator must be ready to take the stopple out of the retort should he observe the liquid ascending in the connecting tube from the middle bottle.

276. The solution of sulphurous acid in the first and second bottles contains a small portion of sulphuric acid, which must be carefully neutralized by a little potassa or soda (in solution), adding it drop by drop till the liquid can destroy the vegetable blues, which it reddens as long as there is any sulphuric acid present. The last bottle contains the purest sulphurous acid.

277. Add a few drops of the vegetable blue of the common coloured cabbage to water in a wine glass, after mixing it with a little of the aqueous solution of the sulphurous acid. The colour is immediately discharged.

278. Add in the next place a few drops of aqueous ammonia. The ammonia overpowers the action of the sulphurous acid, and produces a green compound with the colouring matter.

279. Add aqueous sulphuric acid diluted, drop by drop, till the ammonia is neutralized, and continue till the colour becomes red. The sulphurous acid is now overcome by the excess of sulphuric acid.

280. Neutralize the sulphuric acid by ammonia, when the sulphurous acid again predominates, and the liquid becomes colourless.

281. A very pure solution of sulphurous acid in water may be obtained by heating 100 parts of the binoxide of manganese with 15 of sulphur in an iron bottle, Fig. 17, page 10, or gun-barrel apparatus, Fig. 22, page 13, placed in the open fire, and transmitting it through water. The sulphur combines with part of the oxygen of the binoxide, and comes away in the form of sulphurous acid.

282. Solutions of sulphurous acid soon pass into sulphuric acid when exposed to the air, but may be kept for years in stoppered bottles, with little or no change. Sulphurous acid attracts oxygen from a number of metallic oxides, as those of gold and mercury, precipitating them in the metallic form. Its salts are termed *sulphites*; they are all decomposed with effervescence by the stronger acids; when exposed to air and moisture, they attract oxygen, and become *sulphates*.

SECT. II.—SULPHURIC ACID.

Symb. of THE DRY ACID O^3S *or* $\vdots S$. *Eq. by W.* 40.1 (O. 24+16.1 S). *Eq. by W. of* COMMON AQUEOUS SULPHURIC ACID, 49.1 *(dry acid* 40.1+9 *water)*; *Symb.* $H\vdots S$; *sp. gr.* 1.845; *it boils at* 620° *(Dalton) when sp. gr.* 1.85, *when, the acid and water rise together, condensing without change.*

283. Sulphuric acid is seldom or never prepared on the small scale, large quantities of it being manufactured in this country and on the continent, as objects of commerce. The processes by which it is obtained consist in exposing sulphate of iron to heat in vessels from which it is distilled and collected in a receiver; or in oxygenating sulphurous acid by the action of nitrous acid, or other compounds of nitrogen and oxygen.

284. In the first process, the water of crystallization in the crystallized sulphate is, in a great measure, expelled by heating it over the fire; the salt is then exposed to a red heat in iron vessels, and the acid collected in a receiver. The acid thus procured consists of about two equivalents of dry sulphuric acid (80.2), combined with one of water. It usually contains a small quantity of sulphurous acid derived from the decomposition of a portion of sulphuric acid, caused partly by the high temperature

and partly by the oxide of iron in the sulphate attracting an ad-
ditional quantity of oxygen. In this state it is known by the
name of *glacial oil of vitriol.* Its specific gravity varies from
about 1.80 to 1.98 ; it emits· fumes when exposed to the air,
makes a hissing noise when dropped into water, and boils at
about 100° of F. When exposed to a very gentle heat in a
glass retort connected with a receiver kept cold by ice or snow,
nothing comes over but dry sulphuric acid, which is condensed
in the receiver, and may be obtained, in the solid form by stop-
ping the distillation before any of the water begins to come
along with it. This is termed *anhydrous* (without water).

285. Anhydrous sulphuric acid may also be procured by
heating the sulphate of antimony gradually to redness in a
green glass retort, the receiver being kept very cold.

286. Anhydrous sulphuric acid emits copious fumes on exposure
to the air ; it is very tough, and may be converted into common
sulphuric acid by adding the proper quantity of water. It be-
comes liquid at 68°, and boils at a much lower temperature in
its pure state (about 120°), than when combined with water.

287. Common sulphuric acid, called also *aqueous sulphuric acid*
or *oil of vitriol,* is usually prepared in this country by oxygenat-
ing sulphurous acid and combining it with water. According
to one process, eight or nine parts of sulphur are mixed with one
of nitre, and the mixture burned in a furnace from which the
vapours and gases produced pass into a large room or chamber
lined on every side with lead, and covered to the depth of seve-
ral inches with water. The sulphur is chiefly converted into
sulphurous acid during its combustion ; a portion of it becomes
sulphuric acid by combining with some of the oxygen of the
nitre : nitrous acid and binoxide of nitrogen are disengaged.
The sulphurous and nitrous acids unite with watery vapour,
which they meet with in the atmosphere of the chamber, form-
ing a crystalline compound which is decomposed by the water at
the bottom of the chamber, being converted into sulphuric acid,
which remains in combination with the water, and binoxide of ni-
trogen and nitrous acid which are disengaged. All the binoxide
(which is a light gas), rises in the chamber, and mixing with a
fresh quantity of atmospheric air, combines with the oxygen
and forms a dense ruddy vapour (nitrous acid), which imme-
diately falls down in consequence of its great specific gravity, and

meeting with more sulphurous acid and watery vapour, a crys-
talline compound is again formed, which is resolved as before
into sulphuric acid, binoxide of nitrogen, and nitrous acid. The
same series of combinations and decompositions goes on till the
water at the bottom of the chamber has become strongly acid.
It is then boiled in leaden vessels to expel a part of the water,
and the concentration finished in large glass-retorts heated in a
sand-bath, or in platinum retorts placed over the open fire.

288. The theory of the production of sulphuric acid has been
carefully studied, but the nature of all the changes that ensue
is still imperfectly understood, more especially in the details as
to the number of equivalents of the different substances that are
produced, or meet with each other during its production.   The
following are the principal facts that have been pointed out in
reference to this process.

289. Sulphurous acid and nitrous acid, perfectly dry, do not
react with each other.

290. Sulphurous acid, nitrous acid, and watery vapour, im-
mediately produce a crystalline precipitate, which has been con-
sidered as a compound of sulphuric acid, hyponitrous acid, and
water.   In the following symbolic views, the water is not repre-
sented.

$$\text{Symb. } :S \; \& \; \cdot :N = :S + :N.$$

291. The preceding compound of sulphurous acid, hyponi-
trous acid, and water, is decomposed when it comes in contact
with a large quantity of water, the sulphuric acid combining
with the water, and the hyponitrous acid (two eqs.) being re-
solved into nitrous acid and binoxide of nitrogen.

$$\text{Symb. } 2 :N = \cdot :N \; \& \; :N.$$
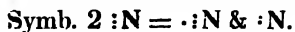
292. The nitrous acid reacts as before, producing more of
the crystalline compound by combining with sulphurous acid
and water.

293. The binoxide of nitrogen rises in the chamber, attracts
oxygen from the air, and becomes heavy nitrous acid, which de-
scends and reacts in the same manner, so that this gas becomes
the medium of communicating a large quantity of oxygen from
the air to the sulphurous acid, returning again and again for
more, after depositing the load it carries when converted into
nitrous acid.

294. A portion of pure nitrogen has also been observed, so

that one portion of nitrous or hyponitrous acid must be entirely decomposed.

295. A little nitric acid is also formed by the action of the water in the chamber on part of the nitrous acid (see Nitrous Acid); but as the liquid becomes more charged with sulphuric acid, this prevents the production of nitric acid, which the water would otherwise effect. Sulphurous acid, by abstracting oxygen, can reduce the nitric to nitrous or hyponitrous acid, which sulphuric acid often retains, even when concentrated. By boiling with a little sulphur, the hyponitrous acid is decomposed, probably with an evolution of the binoxide of nitrogen.

296. In many manufactories, instead of mixing nitre with the sulphur, nitrous and nitric acids, &c., are disengaged by the action of sulphuric acid upon nitre, the mixture being heated by the burning sulphur, which supplies the chamber with sulphurous acid gas. Sometimes the nitre and sulphur are in separate furnaces. Watery vapour is also supplied to the air by introducing it into the chamber by a pipe from a steam-boiler. Instead of nitre, nitrate of soda is now frequently employed.

297. The preparation of sulphuric acid may be illustrated very beautifully on the small scale by making sulphurous acid and nitrous acid gases meet together in a glass vessel; and as the experiment is intended solely for illustration, the sulphurous acid gas may be prepared by the decomposition of sulphuric acid. Into one of the small retorts, (which should be large enough to hold about 3 or 4 ounces of water when full), put 400 grains of mercury and 600 grains of sulphuric acid, and into the other 80 or 90 grains of sugar. Heat the first retort by a chauffer, and when the sulphurous acid begins to come, pour over the sugar 300 grains of aqueous nitric acid, previously diluted with an equal bulk of water, and heat
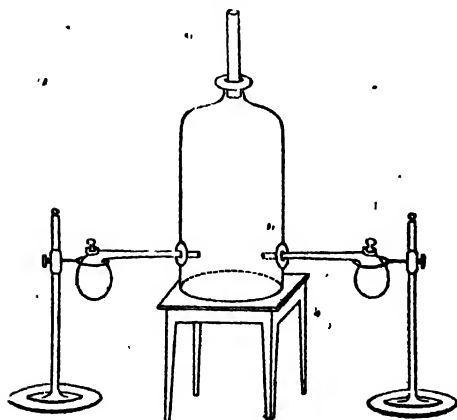
Fig. 102.

the retort gently till the nitrous acid fumes begin to come over.
which are formed by the sugar attracting oxygen from the ni-
tric acid. ‘ When the gases meet in the large bottle (into which
the retorts are fixed by being ground to the tubulures, or hav-
ing their beaks passed through corks fitted to them), a crystal-
line compound is soon deposited on the sides of the vessel in
beautiful dendritical crystals, which often cover its whole inter-
nal surface.   Remove the retorts when ‹either the sulphurous
or nitrous acid ceases to come over, and pour a little water into
the bottle ; a brisk effervescence immediately takes place where
the water comes ‹in contact with the crystalline compound, which
is resolved into binoxide of nitrogen, nitrous acid, and sulphuric
acid, the former producing an additional quantity of ruddy
coloured fumes of nitrous acid, as it comes into contact with the
air, and‹ the latter‹ being retained in combination with the
water.   ‹

298. In this illustrative process for the preparation of sul-
phuric acid, the water which is carried over from the diluted
nitric acid by the nitrous acid vapour, is sufficient for enabling
the nitrous and sulphurous acids to form the crystalline com-
pound (289, 290).

299. Aqueous sulphuric acid is transparent, colourless, and in-
odorous, and has a thick oily appearance when‹poured from one
vessel to another.   It is very acid and corrosive, reddens the
vegetable blues, and tastes extremely sour, even when diluted
with a very large quantity of water.   It absorbs this fluid rapid-
ly from the air, and combines with it in all proportions.   A
considerable elevation of temperature attends the combination :
they must not, accordingly, be mixed in a thick glass-vessel.
The condensation that takes place may be easily seen by pour-
ing sulphuric acid into a long glass-tube till it is about half full,
filling it gently with water, emptying it into a jug or thin glass-
flask, where the water and acid must be agitated together, re-
turning them to the tube when cold.‹ When four parts of acid
by weight are mixed with one of water, both at the temperature
of 50°, it immediately rises to 300°.—Dr Ure. Four parts of
acid and one of ice give a heat about 212° ; but with four of ice
and one of acid, the temperature falls below zero.

300. As it is important‹ to know the quantity of dry acid in
sulphuric acid of different densities, I have inserted the fol-
lowing‹ table drawn up by Dr Ure. The strongest common

sulphuric acid contains 9 parts of water in combination with every 40.1 parts of dry acid, and is hence frequently termed hydro-sulphuric acid or aqueous sulphuric acid ; the latter prefixture is preferred.

Table by Dr Ure, shewing the quantity of Liquid Acid (composed of dry acid 40·1 + 9 water), and Dry Acid, contained in 100 *parts of sulphuric acid, at different densities.*

For example, 100 parts of sulphuric acid of sp. gr. 1·8475 (the 2d in the first column) contain 99 of the acid of the strength specified, the remainder (1) of the 100 parts being water : or 80·72 of dry acid, the remainder (19·28) being water.

Specific Gravity.	Liquid Acid.	Dry Acid.	Specific Gravity.	Liquid Acid.	Dry Acid.	Specific Gravity.	Liquid Acid.	Dry Acid.
1.8485	100	81.54	1.5593	66	53.82	1.2334	32	26.09
1.8475	99	80.72	1.5390	65	53.00	1.2260	31	25.28
1.8460	98	79.90	1.5280	64	52.18	1.2184	30	24.46
1.8439	97	79.09	1.5170	63	51.37	1.2108	29	23.65
1.8410	96	78.28	1.5066	62	50.55	1.2032	28	22.83
1.8376	95	77.46	1.4960	61	49.74	1.1956	27	22.01
1.8336	94	76.65	1.4860	60	48.92	1.1876	26	21.20
1.8290	93	75.83	1.4760	59	48.11	1.1792	25	20.38
1.8233	92	75.02	1.4660	58	47.29	1.1706	24	19.57
1.8179	91	74.20	1.4560	57	46.48	1.1626	23	18.75
1.8115	90	73.39	1.4460	56	45.66	1.1549	22	17.94
1.8043	89	72.57	1.4360	55	44.85	1.1480	21	17.12
1.7962	88	71.75	1.4265	54	44.03	1.1410	20	16.31
1.7870	87	70.94	1.4170	53	43 22	1.1330	19	15.49
1.7774	86	70.12	1.4073	52	42.40	1.1246	18	14.68
1.7673	85	69.31	1.3977	51	41.58	1.1165	17	13.86
1.7570	84	68.49	1.3884	50	40.77	1.1090	16	13.05
1.7465	83	67.68	1.3788	49	39.95	1.1019	15	12.23
1.7360	82	66.86	1.3697	48	39.14	1.0953	14	11.60
1.7245	81	66.05	1.3612	47	38.32	1.0887	13	10.41
1.7120	80	65.23	1.3530	46	37.51	1.0809	12	9.78
1.6993	79	64.42	1.3440	45	36.69	1.0743	11	8.97
1.6870	78	63.60	1.3345	44	35 88	1.0682	10	8.15
1.6750	77	62.78	1.3255	43	35.06	1.0614	9	7.34
1.6630	76	61.97	1.3165	42	34.25	1.0544	8	6.52
1.6520	75	61.15	1.3080	41	33.43	1.0477	7	5.71
1.6415	74	60.34	1.2999	40	32.61	1.0405	6	4.89
1.6321	73	59.52	1.2913	39	31.80	1.0836	5	4.08
1.6204	72	58.71	1.2826	38	30.98	1.0268	4	3.26
1.6090	71	57.89	1.2740	37	30.17	1.0206	3	2.446
1.5975	70	57.08	1.2654	36	29.35	1.0140	2	1.63
1.5868	69	56.26	1.2572	35	28.54	1.0074	1	0.8154
1.5760	68	55.45	1.2490	34	27.72			
1.5648	67	54.63	1.2409	33	26.91			

301. Sulphuric acid has a great affinity for the different sali-
fiable bases, and can disengage almost all the other acids from
their combinations with them. It forms soluble compounds
with the alkalis, but with some of the earths, especially baryta,
the compounds which it forms are very insoluble. Hence
baryta is generally employed as a test of the presence of sul-
phuric acid, giving a copious white precipitate in all solutions
containing it either in a free state or combined with other sub-
stances. A solution of the hydrochlorate or nitrate is the form
in which it is usually applied.

302. The different sulphates may be formed by bringing
sulphuric acid into contact with their respective bases, great
heat being in general produced, so that they must be mixed
cautiously together. Some of these are extensively distributed
throughout the globe, as the sulphate of lime, and many are
prepared in large quantities by artificial operations. The sul-
phates of the common metals are in general decomposed by a red
heat. The earthy and alkaline sulphates resist the action of a
much higher temperature ; but may be decomposed by heating
them along with charcoal, or passing a stream of hydrogen gas
over them at a high temperature, the oxygen both of the sul-
phuric acid and of the metallic oxide being withdrawn, and a
metallic sulphuret remaining. The metallic sulphurets formed
in this manner decompose water, the sulphur combining with
the hydrogen and the metal with the oxygen, forming hydro-
sulphates, which are dissolved when a sufficient quantity of
water is employed.

303. Gay Lussac has lately shewn that when sulphates of the
common metals are decomposed by heating them with charcoal,
the products vary considerably according to the manner in
which the heat is applied. Thus, with the sulphate of zinc,
the following products may be obtained.

I. Oxide of zinc, if the heat does not exceed a dull red.

II. Metallic zinc, if the heat be increased to a cherry red,
after preparing the oxide as in I.

III. Sulphuret of zinc, if the temperature be elevated briskly
from the commencement to a reddish-white heat.

Again, sulphate of lead and charcoal give sulphuret of lead
and carbonic acid. But if there be an excess of sulphate of
lead, the sulphuret of lead decomposes it, and sulphurous acid

and metallic lead are produced. *Symb.* SPb & :S ·Pb ꭓ 2 :S & 2 Pb.

304. Sulphuric acid freezes at — 15° in the state in which it is usually met with in commerce ; but if diluted with water so as to have a specific gravity of 1.78, it shoots into large crystals, when placed in snow or ice, and will remain in a solid form if not exposed to a temperature above 44°. If the proportion of water be increased, it requires a much lower temperature to cause the acid to congeal.

305. By passing sulphuric acid in vapour through a red hot porcelain tube, in the manner already described under nitric acid, it is resolved into sulphurous acid and oxygen : and if these gases are returned through the tube, they will unite and form sulphuric acid, a fact that will not appear so improbable when we reflect on the numerous circumstances by which chemical action is influenced. There are many instances also where an action of a similar kind occurs. Thus, water may be decomposed by electricity, and its elements again combined by the same agent so as to form water ; if a stream of hydrogen gas be transmitted over the oxide of iron at a red heat, it will abstract the oxygen, and water and metallic iron will be produced ; and by transmitting watery vapour over the metallic iron that remains still at a red heat, hydrogen gas may be procured, the oxygen of the iron combining with the water.

306. The sulphuric acid of commerce is never in a state of absolute purity, being always contaminated with small quantities of sulphate of potassa and sulphate of lead. It is the latter that renders common sulphuric acid turbid when diluted with water, sulphate of lead being insoluble in water or diluted sulphuric acid, though the strong acid can dissolve a small quantity. The quantity of these salts may be ascertained by evaporating a known weight of acid to dryness in a platinum crucible. Pure sulphuric acid evaporates without leaving any residuum.

307. It is purified from both these salts by distillation. For this purpose, fill a plain retort (capable of containing 30 or 40 cubic inches) about one-third full of acid, placing the beak within a glass-tube 3 or 4 feet long, and from 1 to 2 inches in diameter. Fig. 103 shews the general arrangement of the apparatus, the connecting tube being represented shorter in the figure than it ought to be. It is not necessary to keep the

tube cold by water, as the acid gives out little heat during its

Fig. 103
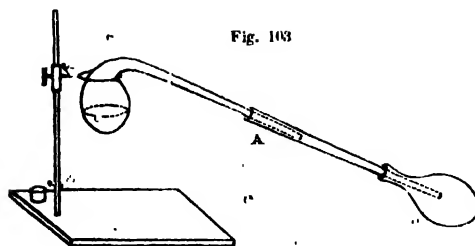
condensation, requiring a very small quantity to convert it into vapour, though it must be exposed to an elevated temperature before it begins to boil. The retort must be heated by a very powerful lamp, or, what is much better, by a chauffer, supplied with a mixture of charcoal and cinders for fuel. The long connecting tube is supported by a retort-stand or otherwise at A.

308. To prevent the occurrence of those violent succussions that are always observed when the acid boils, and which generally break the retort if not moderated in time, put several pieces of platinum wire or foil into the retort along with the acid. Fragments of glass may be used as a substitute for the platinum. Small portions of thin glass-tube are better for this purpose than thick pieces of flat glass.

309. In the present instance, and in many other cases, it is advantageous to support the retort loosely on the ring of the retort-stand in the manner represented in the figure. The base of the retort-stand is also occasionally made of an oblong piece of wood, or of a tinned iron vessel of the same shape, which is filled with water at an aperture above, to protect the table from the heat of a chauffer placed upon it. The latter by itself is a useful addition to a chauffer.

310. Arsenious acid is often found in common aqueous sulphuric acid, the sulphur with which it is prepared being frequently contaminated with arsenious acid. It is precipitated as yellow sulphuret of arsenic by diluting the acid with water, and transmitting hydrosulphuric acid gas through it. If this gas be passed into the concentrated acid, sulphur is precipitated along with the sulphuret of arsenic.

To purify sulphuric acid from arsenious acid, it has been recommended to distil it after mixing it with the hydrated peroxide iron, by which the arsenious acid is retained.

311. There are few agents that are so extensively employed in chemical operations as sulphuric acid. Sometimes it is used to disengage one of the ingredients of a compound by the great affinity which it has to the other. It is used for the preparation of sulphurous acid, in bleaching, dyeing, in making freezing mixtures, in communicating oxygen, and to form a number of important combinations.

SECT. III.—HYPOSULPHUROUS AND HYPOSULPHURIC ACIDS.

312. These acids are comparatively of much less importance than those which have been already considered. A very shor notice of each, therefore, will be considered sufficient in this place.

313. *Hyposulphurous Acid* (Symb. $2 O + 2 S$, or $:S^2$) may be formed by digesting sulphur in a solution of a sulphite (a compound of sulphurous acid and a salifiable base), the two equivalents of oxygen in the sulphurous acid combining with an additional quantity of sulphur, and being thereby converted into one equivalent of hyposulphurous acid. It is not easy to procure this acid in a free state, as it is almost immediately decomposed by the reaction of its elements when detached from the base with which it is combined. Hyposulphurous acid is distinguished by the peculiar relation which it has to the oxide of silver, combining with it in preference to soda, which is easily separated from this acid by the oxide, the only instance where a metallic oxide can separate a fixed alkali from an acid, without the aid of some other affinity. The solution of the hyposulphite of soda, and also of other neutral hyposulphites, dissolves chloride of silver, forming a compound which has a very intense sweet taste, not accompanied by any disagreeable astringency, or any thing that could indicate the presence of a metal.

314. *Hyposulphuric Acid* (Symb. $5 O + 2 S$, or $::S^2$) is prepared by transmitting sulphurous acid through water in which finely powdered binoxide of manganese has been suspended. Heat is evolved, and a portion of the oxygen of the binoxide combines with some of the sulphurous acid and forms sulphuric acid, part of which unites with the remaining sulphurous acid, by

which•the hyposulphuric acid is produced. If the binoxide of manganese be pure, and the mixture kept cool as the sulphurous acid is introduced, little or no free sulphuric acid is formed. Both acids remain in combination with oxide of manganese, which may be precipitated by adding baryta, the sulphuric acid being also thrown down in combination with part of the baryta, while the hyposulphyric acid unites with the rest, and remains in solution. By cautiously adding sulphuric acid to this solution, the baryta is removed, and the hyposulphuric acid remains in solution. It has not been procured free from water, and is resolved into sulphurous and sulphuric acids when exposed to heat, or when its solution is highly concentrated.

Symb. $2 :S \& :Mn = ::S^2 + \cdot Mn$. Two of sulphurous acid, and binoxide of manganese, produce hyposulphate of manganese.

$:S \& :Mn = \cdot S + \cdot Mn$. Sulphurous acid and binoxide of manganese, produce sulphate of manganese.

$\cdot ::S^2 + \cdot Mn \& :S + \cdot Mn \& 2 \cdot Ba = 2 \cdot Mn \& :S + \cdot Ba \& ::S^2 + \cdot Ba$. Hyposulphate of manganese, and sulphate of manganese, and two of baryta, produce two of oxide of manganese, sulphate of baryta, and hyposulphate of baryta (the hyposulphate remains in solution).

$::S^2 + \cdot Ba \& :S = :S + \cdot Ba \& ::S^2$. Hyposulphate of baryta, and sulphuric acid, produce sulphate of baryta, and hyposulphuric acid.

SECT. IV.- -HYDROSULFHURIC ACID OR SULPHURETED HYDROGEN.

Symb. SH. *Eq. by W.* 17·1 ; *by volume* □ *(one measure).* *Sp. gr.* 1.179. *Weight of* 100 *cubic inches* 36·587 *grains. It is liquefied by a pressure of* 17 *atmospheres at* 50°. 100 *c. i. of water absorb* 100 *of this gas.*

315. Hydrosulphuric acid is most easily procured by pouring sulphuric acid, diluted with about three or four times its weight of water, over an equal weight of sulphuret of iron reduced to small fragments, collecting the gas that is disengaged in jars over the pneumatic trough. The materials may be put into a retort, or into a bottle with a bent tube adapted to the tubu-

lure ; the apparatus already described and used for the prepara-
tion of hydrogen gas may also be employed here, and when a
steady current of gas is required, the bottle represented in Fig.
36. page 22, or one constructed on the same principle, will be
found very convenient. The gas may be made to come over
more rapidly by using a stronger acid, and by reducing part of
the sulphuret to powder.

316. Several methods have been proposed for preparing the
sulphuret of iron. By exposing a bar of iron to a white heat
in a furnace or at a smith's forge, and then bringing it in con-
tact with a piece of roll sulphur, it is obtained perhaps more
conveniently than in any other way. The iron combines im-
mediately with the sulphur, forming a liquid which speedily
becomes a solid brittle mass, with a metallic lustre ; it is a sul-
phuret of iron, and the great superiority of this process to the
others consists in the sulphuret formed in this manner contain-
ing no metallic iron and no excess of sulphur ; the former
would cause pure hydrogen to be disengaged along with the
hydrosulphuric acid. When more than one equivalent of sul-
phur is combined with one of iron, it does not afford any gas
when treated with an acid. The roll sulphur should be placed
on a stone and the iron brought in contact with it, gradually
bringing them closer and closer to one another as the sulphuret
is formed ; or they may be held over an iron basin filled with
water, into which the melted sulphuret falls, taking care always
to keep the sulphur and iron in contact with one another. A
shower of sparks is thrown off during the action, and if the sul-
phuret be allowed to fall on the ground, it divides into an in-
finite number of small globules, presenting a very beautiful ap-
pearance ; most of it, however, is lost when it is allowed to fall
to the ground in this manner.* The iron must be at a white
heat, otherwise it merely melts the sulphur, and causes it to
take fire, no sulphuret being formed. The roll sulphur should
be wrapped round with some cloth or cotton where it is to be
held by the hand, or a glove may be put on to prevent it from
falling to pieces. When a long bar of iron cannot be procured,
a smaller piece may be held with a pair of pincers, and care
must be taken to hold the iron and sulphur in the manner re-
presented, Fig. 104, to prevent the liquid sulphuret from run-
ning down the iron and reaching the hand. If the sulphur

Fig. 104.
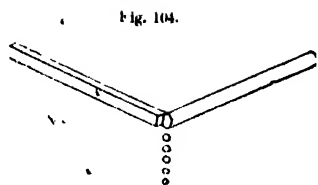
is applied to the middle of the bar when it is at a proper temperature, it may be divided into two parts in a few seconds by pressing the sulphur gently against it. The iron should be taken out of the forge or furnace whenever it has become sufficiently hot, as it would be speedily destroyed if left in the fire at this high temperature.

317. The sulphuret of iron may also be obtained by exposing iron-pyrites to heat in a crucible placed in a furnace till the excess of sulphur which it contains has been expelled. When neither of these methods can be conveniently followed, it may be procured by mixing four parts of sulphur with seven of iron filings, and exposing the mixture to heat in a dry Florence flask (which should not be more than a third full), resting on the red hot cinders in a good chauffer. In a short time the sulphur melts and combines with the iron, a red light pervading the whole mass during the combination : a cork with a small piece cut out at the side (to allow the vapours of sulphur which are formed at first to be disengaged) should be put into the neck of the flask, to prevent the free access of the air. The flask need not be kept over the chauffer after the glow of light has begun to appear, and care must be taken not to press the cork too hard in, lest the vapour of the sulphur not having room to escape freely, should cause an explosion ; the flask is broken afterwards that the sulphuret may be removed. When it is not desired to see the glow of light attending the combination, the mixture may be heated in a crucible or iron ladle. The sulphuret prepared in this manner always has some metallic iron mixed with it, but the hydrosulphuric acid which it affords is sufficiently pure for all ordinary experiments.

318. The richness of the tint presented by the light evolved during the combination of the sulphur and iron depends principally upon its being seen through a film of sulphur condensed and subsequently melted upon the inside of the upper part of the flask. If we expel this sulphur by heating the upper part of the flask, or look through any part of the glass when none is deposited, nothing but a dull red light is perceived.

319. The theory of the preparation of this gas is very simple. A reaction takes place between every nine parts of water (one

eq.) and 44.1 (one eq.) of the sulphuret of iron, the latter being composed of 16.1 of sulphur and 28 of iron. The oxygen of the water combines with the iron of the sulphuret, forming oxide of iron, with which one equivalent of the acid unites, converting it into sulphate of iron, which remains in solution. while the sulphur and the hydrogen combine together to form hydrosulphuric acid. The following diagram is intended to illustrate the decomposition.

Fig. 105.

Before decomposition.			After decomposition.
9 Water	Hyd.	1	17.1 Hydrosulphuric Acid.
	Ox.	8	
44.1 Sulphuret of	Sulph.	16.1	
Iron	Iron	28	
40.1 Sulphuric Acid		40.1	76.1 Sulphate of Iron.

Symb. ·H ꞉S &·S Fe꞊ HS& ꞉S ·Fe.
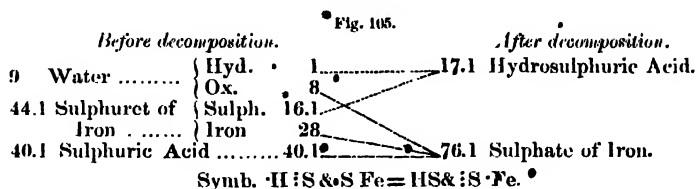
320. Instead of diluted sulphuric acid, aqueous hydrochloric acid diluted with an equal bulk of water may be used with the sulphuret of iron. Hydrochlorate of iron then being formed in the same manner as sulphate of iron is formed with the aqueous sulphuric acid.

Symb. HCl & ·H & SFe ꞊ HCl ·Fe & HS.

321. When hydrosulphuric acid is required particularly pure, sulphuret of antimony reduced to powder is mixed with five times its weight of hydrochloric acid, the antimony being oxidated by the water which the acid contains, while the sulphur combining with the hydrogen that is set at liberty forms the gas that is evolved.

322. Hydrosulphuric acid gas has lately been frequently prepared from the sulphurets of potassium and calcium by the action of a diluted acid ; but there is perhaps no process so convenient as that already described with sulphuric acid, water, and sulphuret of iron.

323. As hydrosulphuric acid has not only an extremely offensive odour (similar to that of sulphureous mineral waters), but produces severe headach when it is mixed even in small proportion with atmospheric air, none should be allowed to escape into the apartment in which it is prepared. A small quantity, indeed, such as is usually lost during its preparation, will not do any harm ; but where the materials from which it

has been procured have been carelessly thrown aside before the gas has ceased to come, it goes on accumulating, and often produces very deleterious effects. I have seen several people very much affected by the gas disengaged, even from a small quantity of materials set aside in a corner of a very large room ; one of them felt so much depressed, that for two days almost he lay in a listless state, and was unable for a long time to hold up his head, after which he gradually recovered ; in this case, the individual most affected had been engaged for about four hours in the apartment referred to, in which the hydrosulphuric acid was calculated to have formed not more than a five thousandth part of the bulk of the atmospheric air. It is indeed much more noxious to animal life than would have at first been anticipated ; a horse dies in air containing even $\frac{1}{1500}$th of its bulk of this gas, and dogs and smaller animals when the quantity is so small as $\frac{1}{800}$th part ; a small bird died instantly in air containing $\frac{1}{1500}$th part. Chaussier states, that many animals die soon if they are put into bladders full of this gas, though their heads are left out, and they are allowed to breathe atmospheric air as freely as before.

324. Hydrosulphuric acid burns with a pale blue lambent flame when kindled in contact with atmospheric air or oxygen gas. During its combustion, the hydrogen combines with the oxygen of the air, forming water, while the sulphur uniting with the same element is converted into sulphureous acid. Mixed with $1\frac{1}{2}$ times its bulk of oxygen it detonates on applying a lighted match. A stout glass bottle must be used for this experiment, though the detonation is not quite so violent as with many other gases.

325. The combustion is never complete in atmospheric air, part of the sulphur being always deposited on the sides of the vessel in which it is inflamed ; when mixed with pure oxygen however, in the proportion just mentioned, the combustion is always complete.

326. Water absorbs hydrosulphuric acid readily, taking up more than its own volume when previously deprived of air by boiling, and acquiring its peculiar odour. On exposure to the air, part of the hydrosulphuric acid escapes, and the remainder is decomposed, the water acquiring an opalescent appearance

from the deposition of a portion of sulphur, or bisulphureted hydrogen.

227. Hydrosulphuric acid reddens the infusion of litmus, and possesses the other properties of an acid. The red tint which it communicates to the solution is not permanent, ceasing when the gas escapes or is decomposed. If the reddened infusion be boiled, the gas is soon expelled and it becomes blue, which may be easily seen by heating a small quantity in a Florence flask, or test tube. Frequently the litmus becomes entirely colourless after boiling, and in such cases, the colour occasionally returns after the liquid has become thoroughly cold, and been exposed to the air. The solution of hydrosulphuric acid may be kept for years in bottles well corked and sealed; they ought also to be filled perfectly full. Perhaps the most convenient method of preparing a small quantity of the solution of this gas is to fill bottles about two-thirds full with the gas over the pneumatic trough, and to agitate the remaining water briskly with it as long as it continues to absorb any, taking out the cork from time to time to allow atmospheric air to enter and supply the place of the gas as it combines with the water.

328. Fuming nitric acid decomposes hydrosulphuric acid, communicating oxygen to the hydrogen, while the sulphur is deposited: if a piece of thick paper be placed over the bottle containing the gas whenever the acid is poured in, and the finger pressed very gently upon it so as to prevent any gas escaping, the temperature rises so high that the sulphur and any undecomposed hydrosulphuric acid immediately take fire, burning with a beautiful flame, and producing a slight detonation; the experiment may be performed with a flask or bottle containing a few cubic inches of the gas with perfect safety. It succeeds, it has been affirmed, only when the hydrosulphuric acid has been prepared by diluted sulphuric acid and sulphuret of iron.

329. Mix three volumes of hydrosulphuric acid with two of sulphurous acid, in a jar over a mercurial trough; they condense into a solid compound, which is the hydrosulphurous acid of Dr Thomson. It has not been applied to any use.

330. Chlorine, iodine, and bromine decompose this gas, combining with the hydrogen and precipitating the sulphur.

331. Hydrosulphuric acid is very much employed as a reagent for detecting a number of the metals, or separating them from

various liquids, as in the detection of arsenic, where the sulphur unites with the metallic arsenic, forming a rich yellow-coloured precipitate if the liquid under examination contain arsenic. In general the sulphur combines with the metal in solution, forming a metallic sulphuret which is precipitated, while the oxygen previously in combination with the metal unites with the hydrogen of the gas. The solutions of the common metals which it does not decompose are those of iron, nickel, cobalt, manganese. titanium, and molybdenum. *(Dr Henry.)*

332. In using hydrosulphuric acid as a test, nitric acid, and still more especially nitrous acid, ought to be avoided, as they not only tend to decompose it, but also give erroneous indications by precipitating sulphur.

333. Solutions of the common metals which are not affected by hydrosulphuric acid gas, are in general precipitated on adding hydrosulphate of ammonia. The alkali (the ammonia) removes any acid or other substance that may be combined with the metal or metallic oxide in solution, and allows the hydrosulphuric acid to act without restraint upon it.

334. A bottle with a bent tube, Fig. 106, adapted to it, may answer for transmitting the hydrosulphuric acid gas through the liquid under examination. A small apparatus, of the construction represented in Fig. 36. page 22, is better. It should be supported on a block of wood, that it may be easily removed, and more acid added to it if necessary. The bent tube should be made to pass to the bottom of the vessel containing the liquid on which the gas is to act. The apparatus represented by Fig. 82, page 68, is employed when it is required to collect the excess of hydrosulphuric acid over a pneumatic trough, the gas being generated in the first bottle and passed through the liquid in the second. Woulfe's apparatus may also be used for the same purpose, but none will be found so generally useful and convenient as a common bottle with a bent tube, putting it and the liquid through which the gas is *passing* in such a situation that the excess shall be carried away without annoying the operator.

335. The most delicate test of hydrosulphuric acid is carbonate of lead, which is converted into a sulphuret of lead by the

action of this gas, becoming perfectly black ; water is formed at the same time, and carbonic acid evolved.

Symb. HS & :C ·Pb = S Pb, & ·II & :C.

Air containing even a 20,000dth part of its bulk of hydrosulphuric acid acts on carbonate of lead, the basis of most white paints.

336. All hydrosulphates (compounds of this acid with the salifiable bases) may, in general, be formed by passing a stream of hydrosulphuric acid gas through a solution of the different bases dissolved or suspended in water ; or by indirect processes, where the hydrosulphuric acid and the base are presented to each other in a nascent state. The most important will be described under their respective bases.

337. All the hydrosulphates are decomposed by heat, but the nature of the resulting compound varies according to the base with which the hydrosulphuric acid is combined. Magnesia parts with all its hydrosulphuric acid ; potassa and soda give off hydrogen and hydrosulphuric acid, part of the sulphur being retained ; and the hydrosulphates of manganese, zinc, iron, tin, and antimony, are converted into water and metallic sulphurets. *(Dr Ure.)*

SECT. V.—BISULPHURETED HYDROGEN ; *called also Hydroper-sulphuric Acid, Hydrobisulphuric Acid, Persulphureted Hydro-gen, and Sulphureted Hydrosulphuric Acid. Thenard considers that there are several compounds containing an excess of sulphur combined with hydrogen.*

Symb. S²H. *Eq. by W.* 33.2 ; (S. 32.2 + 2 II).

338. Bisulphureted hydrogen is prepared by adding a solution of the sulphureted hydrosulphate of lime to an equal bulk of hydrochloric acid. A quantity of sulphur is immediately precipitated, and the bisulphureted hydrogen is slowly deposited in the form of a viscid oily-looking substance of a yellow colour. Its smell is disagreeable, it is inflammable, and is speedily decomposed when gently heated or exposed to the air, hydrosulphuric acid being disengaged, and sulphur deposited.

339. Bisulphureted hydrogen has not hitherto been applied to any important practical purpose. It resembles much the binoxide of hydrogen in the extreme facility with which it is

decomposed, and the combination may be subverted by many of the same agents which so readily decompose the binoxide.

340. Add a grain or two of oxide of silver in fine powder to a few drops of the bisulphureted hydrogen. The oxide is instantly reduced, hydrosulphuric acid is disengaged, and heat and light are evolved, the metal becoming incandescent.

341. Add in the same manner to another portion of the bisulphureted hydrogen, a small quantity of binoxide of manganese ; an effervescence immediately takes place, hydrosulphuric acid gas being disengaged. Proceed in the same way with charcoal in fine powder, sand, or oxide of mercury. Aqueous ammonia also acts rapidly upon this substance, part of the sulphur being precipitated.

342. The SULPHURETED HYDROSULPHATES may be prepared by digesting solutions of the hydrosulphates with flowers of sulphur. Rub the sulphur with a drop or two of the liquid in a mortar at first, that they may mix more easily together, the sulphur resting on the top of the liquid for a long time, when this precaution is not taken.

343. The sulphureted hydrosulphates of the alkalis and earths are almost the only combinations of this kind that have been frequently prepared, but their chemical history is still imperfect. They also contain compounds of sulphur and oxygen as well as bisulphureted hydrogen, in the form in which they are usually prepared.

344. Prepare the sulphureted hydrosulphate of lime by boiling 320 grains of hydrate of lime with 560 of sulphur, in six or seven times their weight of water, till a deep amber-coloured liquor appears on the top on allowing it to rest for a few seconds. No oxygen is evolved, though it is generally considered that a portion of water is decomposed and bisulphureted hydrogen formed. It is probable therefore, on this supposition, that some compound of sulphur and oxygen is produced, and unites with part of the lime ; the remainder of the lime uniting with the bisulphureted hydrogen. Dr Dalton, however, terms the compound *quadri-sulphuret of lime.*

345. The colour of these solutions varies from a greenish-yellow to a reddish-orange. They are distinguished by their disagreeable odour, bitter taste, and by absorbing oxygen readily from the air, or any gaseous mixture containing it ; a property

in consequence of which they have been much employed in eudiometrical experiments. They are all decomposed by the acids, and when the solution is dilute, a copious precipitation of sulphur takes place. Little or no hydrosulphuric acid is disengaged unless a very concentrated solution and a strong acid be employed, and hence it is presumed that, on the addition of an acid which has a great affinity for the base contained in one of these solutions, the oxygen of the hyposulphurous acid (supposing that to be the compound which the oxygen of the water that is decomposed forms with the sulphur) combines with the hydrogen of the bisulphureted hydrogen, and the sulphur of both is precipitated.

346. It is in this manner that the precipitated sulphur of the London College is prepared, formerly called Lac Sulphuris or Milk of Sulphur. See 258, page 84. A sulphureted hydrosulphate of lime is prepared by boiling one part by weight of sulphur with two of lime and about forty of water; the resulting liquid is filtered through paper, and decomposed immediately by hydrochloric acid, which is added as long as it causes any precipitation. The quantity of lime recommended by the College is considerably more than is required; one eq. of lime is sufficient to render four eqs. of sulphur soluble in water. (*Dalton.*)

347. When sulphuric acid is used instead of hydrochloric acid to precipitate the sulphur, sulphate of lime is precipitated along with it. This substance may be easily detected when mixed with sulphur, by exposing a small quantity to heat in a crucible placed in the fire, or still more easily by the blowpipe; the sulphur is dissipated, but any sulphate of lime which may be present remains.

348. When these solutions absorb oxygen, they lose their disagreeable smell, their colour becomes lighter, and a portion of sulphur is deposited. By long exposure to the air, they become quite colourless, the sulphur being converted into sulphurous and sulphuric acids. They tarnish the metals, and give precipitates with a number of metallic solutions. They must be kept in bottles well closed with glass stopples, or corks made perfectly air-tight with a little wax-lute.

CHAP. V.—SELENIUM.

Symb. Se.   *Eq. by W.* 40; *sp. gr.* 4.5.

349. SELENIUM is an elementary substance which was discovered a few years ago by Berzelius, in sulphur prepared by sublimation from iron-pyrites.   It has hitherto been obtained only in small quantity, and has not been applied to any use. As it will be seldom made the subject of experiment by those commencing the study of chemistry, it may be sufficient in this place to refer to the 13th volume of the Annals of Philosophy, where the process for preparing it. is described.   It is a solid substance, of a dark, brown colour. and metallic lustre, melts at 229°, boils at 600°, forming a yellow-coloured vapour, which condenses in a powdery form like the flowers of sulphur, but of a red colour.   It combines with oxygen when heated in the air, producing a strong smell, similar to that of horse-radish.   The products are oxide of selenium, and a small quantity of an acid, at one time called the selenic acid, but now selenious acid, in consequence of another acid compound having been discovered containing a larger quantity of oxygen.

350. The selenic acid bears a great resemblance to the sulphuric acid in all its chemical habitudes with the different salifiable bases ; and selenium, indeed, in most of its combinations, produces compounds analogous to those which sulphur forms with the same substances.

351. Selenium and hydrogen unite together when the selenuret of potassium acts on water, the oxygen of the water combining with the potassium, and forming potassa, while the selenium unites with the hydrogen.   On adding hydrochloric acid to the compound of selenureted hydrogen and potassa which remains, the former is disengaged in the gaseous form, while the hydrochloric acid combines with the potassa.   It possesses all the properties of an acid, and may be termed hydroselenic acid.

CHAP. VI.—PHOSPHORUS.

Symb. P. *Eq. by W.* 15.7; *sp. gr.* 1.7. *It melts at* 100°, *and vaporizes at* 550°.

352. When bones are burnt to whiteness in an open fire, all the animal matter which they contain is dissipated, and nothing remains but a solid mass of a fine white colour, consisting almost entirely of phosphate of lime, a compound of phosphoric acid and lime. It is from this that phosphorus is usually prepared. A superphosphate of lime is formed in the first place, by mixing the phosphate in fine powder with three-fourths of its weight of sulphuric acid previously diluted with an equal weight of water. The mixture should be made in a large wedgewood mortar, stirring it constantly, and adding water from time to time, till the mass becomes quite fluid and of a uniform consistence. The sulphuric acid combines with the greater part of the lime, and the phosphoric acid set at liberty attaches itself to a portion of the phosphate which is not decomposed, forming superphos- phate of lime. After the mixture has been kept for a day or two, stirring it frequently, and adding more water to keep it quite fluid, it is put into a linen bag. The superphosphate of lime, which is dissolved by the water, filters into a receiver placed below, while the sulphate of lime remains. More water is poured upon the mass as long as the liquor which passes through is sensibly acid; and the filtered solutions are then evaporated till they assume a syrupy consistence, when they are to be mixed with as much powdered charcoal as may render them solid. On drying the mixture, and exposing it in an earthen retort to a strong heat in a furnace, phosphorus is disengaged, and as it is easily volatilized, it may be collected by connecting the beak of the retort with a tin tube which is made to dip into water.

Fig. 107.

353. In the annexed figure (107) taken partly from Mitscherlich's arrangement of apparatus for this pur-

pose, *a* is the body of the earthen retort, *b* the wide tube lead-
ing the gas and phosphorus into the receiver *c*, from which the
gas escapes by the long small tube.
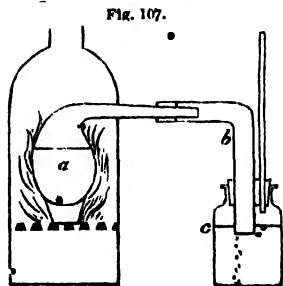
354. In conducting this operation, a very large quantity of
gas is disengaged, which inflames when it comes in contact with
the air. To prevent accident, from the phosphorus congealing,
the tube ought not to be long or narrow, and always kept as
warm as possible.

355. The materials should be well dried by exposure to heat
in an iron ladle or crucible placed over an open fire, before they
are put into the retort, to prevent them from swelling and boil-
ing over. The retort should be coated with Willis's lute (see
Lutes), which prevents the phosphorus from passing through the
pores of the retort, through which it easily forces its way at a
high temperature' when this precaution is not adopted. The
superphosphate of lime does better for the preparation of phos-
phorus than phosphoric acid, as it is not so apt to be volatilized.

356. In this process the carbon combines with the oxygen of
the phosphoric acid in excess in the superphosphate of lime, and
forms part of the gaseous products which are disengaged; phos-
phureted hydrogen gas is also produced by the combination of a
portion of phosphorus with some of the hydrogen of the water
that is always united with this acid, when prepared in the man-
ner that has been described.

357. If it be required merely to illustrate the principle on
which phosphorus is prepared, and not to procure any quantity
of it, which may now be always purchased from the manufac-
turer, thirty or fifty grains of a mixture of phosphoric acid (or
of the superphosphate of lime prepared in the manner mentioned),
with half its weight of charcoal, may be put into a green glass-
tube sealed at one end, about a foot in length and half an inch
in diameter. The tube should be coated with a mixture of two
parts of clay and one of sand, previously mixed with cut thread
or flax, and then have iron wire wrapped round it. The coating
need not extend farther than an inch beyond the part to which
the mixture reaches when it has been introduced, as this alone
is to be exposed to heat. It is placed in a chauffer with a hole
cut in the side, in the manner shewn in the following figure, and
a chimney placed over it (page 5) to increase the heat; the tube
should be gently inclined downwards, to carry off any watery

Fig. 108.
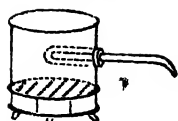
vapour that may be disengaged and condensed on its sides, and the end which is not coated had better be drawn out at the blowpipe when the mixture has been put in, till it is about a quarter or an eighth of an inch in diameter. A green glass-tube is much better than one made of flint-glass, as it is not so easily melted. A mixture of red-hot cinders and charcoal gives the best fire for this experiment. The phosphorus soon begins to come, condensing along the sides of the tube, and a flame appears at the open end, similar to what is produced by the combustion of phosphorus. If the tube be broken off above the point where it is coated, after gas ceases to be disengaged, on blowing through it, the phosphorus immediately takes fire and burns with a vivid light.

358. Phosphorus was formerly prepared from urine, by exposing it, after being evaporated to dryness, to a high temperature, the carbon of the animal matter decomposing the phosphoric acid which it also contains. By adding a solution of the nitrate of lead to it, phosphate of lead is precipitated, which yields it more readily, when mixed with about a fourth of its weight of charcoal. The same compound may be obtained by adding a solution of the phosphate of soda to a solution of the acetate of lead, phosphate of lead being thrown down, and acetate of soda remaining in solution.

359. The phosphorus obtained in these processes is never pure, having a reddish-brown colour which arises from the presence of some phosphuret of carbon formed during the distillation. It is purified most effectually by a second distillation; but for ordinary purposes it will be sufficient to melt it in hot water and press it through chamois leather under water.

360. The distillation of phosphorus may be conducted in a small glass-retort, the phosphorus being covered with water to the depth of about a quarter of an inch before applying heat, and the beak of the retort inserted into a receiver containing a small quantity of water, and dipping under its surface. A strong and steady heat is then applied to the bottom of the retort by an argand or common spirit-lamp; the phosphorus is melted, the water boils and is condensed in the receiver by the cold water, which soon becomes heated to the temperature of 212°, and is thereby not so liable to be forced back into the retort when all

the water has been distilled over. The heat should then be gradually increased by bringing the lamp nearer the bottom of the retort, and the phosphorus is speedily volatilized, condensing in the tube of the retort and dropping into the receiver. When the last-portion of phosphorus is converted into vapour, the beak of the retort may be lifted out of the water in the receiver, and placed in a small cup or saucer with a little hot water in it (no more than is sufficient to cover the beak), and in the same manner as the retort for preparing oxide of nitrogen, Fig. 71, page 48. All this time the lamp must not be shifted, and the heat must be maintained as steadily as before; but when the retort has been adjusted in the manner described, the heat may be withdrawn. The vapour of phosphorus still remaining in the retort soon condenses; the water rises in the tube, but as the quantity is so small, atmospheric air enters before it has proceeded far, when it again falls, and continues rising and falling till the retort has become cold. The small quantity of air which enters at a time in this manner prevents any violent action taking place; its oxygen combines with some of the phosphorus still remaining in the retort, a lambent phosphorescent flame appearing in the neck, and at last the retort is filled with nitrogen gas. When cold, the phosphorus adhering to the retort may be removed by boiling more water in it, but this must not be mixed with the rest, as it contains the most of the phosphuret of carbon, which generally condenses in the neck, forming a crust of a rich red colour.

361. In conducting the distillation of phosphorus, some prefer filling the retort full of water after the phosphorus to be distilled has been introduced, and replacing it by nitrogen gas.

362. The phosphorus obtained by distillation is transparent, and has little or no colour. It may be procured in the form of sticks, by melting it in hot water, and pouring it into glass-tubes slightly tapered and closed at one end by a cork. The tube must also be placed in hot water; the phosphorus being heavier than this liquid sinks in the tube and displaces the water. It is of a waxy consistence at natural temperatures, and may be easily cut with a knife.

363. In all experiments with phosphorus, great care must be taken not to allow it to come into contact with air when melted or exposed even to a very gentle heat, if it be not required to

kindle it, as it is apt to take fire, even when gently pressed between the fingers, or when heated a very little above its melting point. It ought also to be cut under water, as it frequently takes fire when cut in the open air; and should never be held by the fingers. Accidents are continually taking place from not attending to these precautions. It must be kept in bottles filled with water, and should not be exposed to the light, as it then soon acquires a crust upon its surface. When phosphorus is to be inflamed in atmospheric air or oxygen gas, it must always be well dried on bibulous paper, which prevents it from throwing out sparks.

364. Phosphorus appears luminous in the dark when surrounded by atmospheric air, and traces drawn on the wall with it (holding it with a pair of pincers, and having the hands protected by gloves) present a beautiful phosphorescent appearance; a basin of water should always be at hand when this is done, in case the friction should cause it to take fire. It appears that this luminousness depends upon a small portion of phosphorus being dissolved by the nitrogen of the air, which combines with the oxygen when in this minute state of division; for when phosphorus is enclosed in a jar with pure oxygen, little or no action takes place at ordinary temperatures. When water is boiled with a little phosphorus, part of it rises in vapour along with the steam, and renders it luminous when it comes in contact with the air. If the steam be made to issue from a small aperture, it presents a luminous cone, which is incapable, however, of inflaming any combustible matter.

365. Phosphorus is insoluble in water, but is dissolved by alcohol, ether, and fixed and volatile oils. The solutions are effected easily by heating these different liquids with the phosphorus in a flask. They are luminous in the dark when exposed to the air.

366. Cut several thin slices of phosphorus; dry them on bibulous paper, by moving them from place to place upon it, but never touching them with the fingers; and heap them loosely together in a little tow or cotton. A slow combustion goes on, which often increases till the phosphorus inflames, but the result is affected so much by the currents induced in the air, and upon the manner in which the small portions of phosphorus touch each other; that it is impossible to predict the result.

367. Phosphorus does not undergo slow combustion in oxygen unless heated to 80°. But if the oxygen be mixed with air, nitrogen, hydrogen, or carbonic acid, minute portions of the phosphorus are dissolved by these substances, and the slow combustion can then go on at 60°. Professor Graham has shewn that

1–150th part of sulphuric ether vapour,
1–450 ...... olefiant gas,
1–1820 .... naphtha vapour,
1–4444 ... .. oil of turpentine vapour,

prevent the slow combustion of phosphorus at 66°, and retard or diminish it at higher temperatures.

368. When phosphorus is inflamed in atmospheric air, a large quantity of white fumes is formed, which may be collected by including the phosphorus in a glass jar. These consist of meta-phosphoric acid formed by the union of the phosphorus with the oxygen of the air, falling down in the jar like flakes of snow. Great heat and light are produced during its combustion. The apparatus represented by Fig. 69, page 45, may be used for this purpose, placing it upon a brass plate, which ought to be perfectly dry, as the phosphoric acid is extremely deliquescent.

369. When phosphorus is burnt in oxygen gas, the combustion is very brilliant, and an intense dazzling light is produced, which, however, is of short duration. The phosphorus (previously well dried) may be placed in a copper cup suspended by a wire from a small plate of copper, Fig. 73, page 50, and kindled by touching it with a hot wire when it has been put into a bottle or vase

Fig. 109.

filled with oxygen. When a very large quantity of gas is used, a vessel of the form represented in the adjoining figure, will be found very convenient. It is filled with water after putting a cork into the opening at the top, placed on the shelf of a large pneumatic trough, in the same manner as a jar, and oxygen gas introduced by the lower aperture. When quite full, it is allowed to drain, removed on a flat plate of brass, the cork taken out, and a thin plate of copper placed over the top. Sand to the depth of half an inch being placed where the jar is to rest, and the phosphorus in a small cup being kindled by an iron wire, the vessel of oxygen is placed over it. The copper plate allows part of the oxygen to escape freely

when expanded by the heat. Corks should never be kept in during the combustion, as they are generally set on fire ; and, if part of the expanded air cannot get out easily in consequence of the cork getting fixed, the apparatus will in general be blown to pieces. It is often broken, also, when a large quantity of phosphorus is employed. 100 cubic inches of oxygen can combine with about 24 grains of phosphorus, but 8 or 10 grains will be sufficient in this experiment.

370. The apparatus shewn in Fig. 69, p. 45, and Fig. 95, p. 84, do extremely well for the combustion of small quantities of phosphorus in oxygen.

371. Phosphorus may be inflamed under water by driving a stream of oxygen upon it, putting a few grains into a glass, and pouring boiling water over it, till it is half full. The oxygen should be made to issue from a small brass nozzle held in con-

Fig. 110.

tact with the melted phosphorus, as in the annexed figure, and connected with a gasometer (or a bladder containing oxygen) by a flexible tube. The aperture at the pointed extremity of the nozzle need not be more than $\frac{1}{50}$th of an inch in diameter. The products of the action are an acid compound in solution, and a brownish-coloured oxide of phosphorus left in minute fragments, and mixed in general with unconsumed phosphorus.
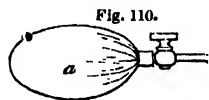
372. If a thin piece of phosphorus be dried, folded in paper, and rubbed with a piece of wood or any solid substance, it immediately takes fire.

373. Metaphosphoric acid alone is formed during the combustion of phosphorus in oxygen gas, but when it is heated in air which has been rarefied to a very great degree, or inflamed in a quantity of atmospheric air not sufficient to supply oxygen for its combustion, both phosphorous and metaphosphoric acids are formed. These are also mixed with another substance of a red colour which contains a smaller proportion of oxygen than phosphorous acid, and has been regarded as a compound of three of phosphorus with one of oxygen. It has, accordingly, been termed the TRITOXIDE of PHOSPHORUS.

SECT. I.—HYPOPHOSPHOROUS ACID.

Symb OP² *or* ·P². *Eq. by* W.·39.4 (O.8 + 31.4 P).

374. Boil water with phosphuret of barium. Part of the water is decomposed ; a portion of the phosphorus combines with the hydrogen of the water, forming phosphureted hydrogen which escapes, and other portions produce hypophosphorus and phosphoric acids, by combining with its oxygen. These acids unite with baryta, the phosphate of baryta, which is insoluble, being left, while the hypophosphite of baryta may be removed in solution by water.

375. To the solution of the hypophosphite gradually add diluted sulphuric acid, till no further precipitate appears ; filter, that the sulphate of baryta formed in this manner may be separated ; the solution contains the hypophosphorous acid.

376. The solution of the acid may be concentrated till it becomes viscid and crystalline. When subjected to an increased heat, the acid and water react upon each other ; part of the acid acquiring oxygen from the water and also from another portion of acid which is decomposed, and producing phosphoric acid ; while the phosphorus of the decomposed acid, along with the hydrogen of the water, form phosphureted hydrogen. All its salts are soluble ; and it is a powerful deoxidating agent.

SECT. II.—PHOSPHOROUS ACID.

Symb. O³ + P² *or* ³P². *Eq. by W.* 55.4 = *Oxygen* 24 + *Phosphorus* 31.4.

377. *Phosphorous Acid* is formed when phosphorus is inflamed in a smaller quantity of air than is necessary for its complete combustion, and even when phosphorus is exposed to the air at natural temperatures. It is mixed, however, with phosphoric or metaphosphoric acid. The process best adapted for preparing it in a pure state, was pointed out by Sir H. Davy. A piece of dry phosphorus is put into a tube retort, and bichloride of mercury in powder placed over it. On exposing the retort to heat, the phosphorus, as it rises in vapour through the bichloride, takes

one proportion of chlorine from it, and a limpid fluid condenses in the receiver, a compound of chlorine and phosphorus. On mixing it with water, they mutually decompose each other, the chlorine combining with the hydrogen of a portion of the water, and forming hydrochloric acid, while the phosphorus takes the oxygen, and is converted into phosphorous acid; by heating the liquid till it becomes of a thick consistence, all the hydrochloric acid and most of the water are driven off, and the phosphorous 'acid, still combined with a portion of water, becomes a solid crystalline mass on cooling.

378. It has a sour taste and a disagreeable fetid smell. It reddens the vegetable blues, and when exposed to heat it is decomposed, a portion of phosphureted hydrogen being disengaged, and phosphoric acid remaining. It is a powerful deoxidating agent, and precipitates gold, silver, mercury, and platinum in the metallic form.

Sect. III.—Phosphoric, Pyrophosphoric, and Metaphosphoric Acids.

Symb. ::P². *Eq. by* W. 71.7 = *Oxygen* 40 + 31.7 *Phosphorus.*

379. Professor Clarke has shewn that the phosphoric acid, without undergoing any change of composition, is altered in its properties by subjecting it to heat, and can be restored again to its original condition by boiling it with water. Professor Graham has added to the interest of this subject by shewing that it is susceptible of a farther modification. The three different conditions of this acid require particular notice.

380. Phosphoric Acid can exist only in solution, or in combination with three eqs. of water, or other substances. Water can act the part of a salifiable base in some of its combinations, or it may replace one, as in one of the phosphates of soda, where one eq. of acid is combined with one of water and two of soda. In this condition it is termed *basic water*. Again, phosphoric acid dissolved in much water, is considered in reality to be more specially in combination with three equivalents of water, a triphosphate of water being produced, which is supposed to be dissolved by the other portions of water. The method of procuring it is described in par. 392.

381. PYROPHOSPHORIC ACID is a modification of common phosphoric acid discovered by Professor Clarke. It is formed when a concentrated solution of phosphoric acid is heated to 415°. Neutralized by ammonia, a *white* granular precipitate is formed on adding nitrate of silver, by the colour of which it is distinguished from the phosphoric acid (393).   The solution of pyrophosphoric acid is supposed to contain two eqs. of water combined with the acid, this compound being dissolved by the remaining water.   It returns to the condition of phosphoric acid when boiled with water.   Its salts, also, the pyrophosphates, are returned to phosphates by boiling in the same manner.   To procure a pyrophosphate, one eq. of phosphoric acid is heated with two eqs. of soda or potassa.   By heating to redness the common phosphate of soda, one equivalent of water is expelled (basic water) besides the water of crystallization, and pyrophosphate of soda is left, containing one eq. of acid and two of soda.

382. METAPHOSPHORIC ACID is produced by burning phosphorus in dry atmospheric air or oxygen.   It is then anhydrous, and is deposited in the form of light flocculi, resembling snow. No more phosphorus should be used than can be supplied freely with oxygen, to prevent the formation of phosphorous acid. Metaphosphoric acid may also be obtained in combination with water, by heating to redness the aqueous phosphoric or pyrophosphoric acid.   A higher temperature volatilizes the water and acid in combination.

383. Procured in this manner, it presents the appearance of glass, and is often termed *glacial phosphoric acid.*

384. Prepare anhydrous metaphosphoric acid by burning Fig. 111. phosphorus in air, supporting it on a copper or iron cup, Fig. 111, and placing it upon a plate of metal or glass, a large glass shade or jar being placed over it, as in Fig. 69, page 45, that the acid may be collected upon the plate.

385. Expose a portion of the white and bulky metaphosphoric acid to the air.   It soon attracts moisture, and becomes fluid.

386. Pour a few drops of water upon another portion in a wine glass.   The water combines with the acid, producing a hissing noise.   Mix some albumen with a solution of the acid produced in this manner.   The albumen is immediately coagulated.

387. Add a solution of metaphosphoric acid to a salt of baryta; metaphosphate of baryta is precipitated.

388. Add another portion to a solution of the nitrate of silver. Metaphosphate of silver is precipitated of a white colour, with a shade of grey.

389. The phosphoric acid is usually procured from the solution of the superphosphate of lime (352), which always contains a small quantity of the sulphate of lime, when prepared from the phosphate by sulphuric acid. Carbonate of ammonia is added to this liquid till it is completely neutralized (as long as any precipitation takes place); the excess of phosphoric acid combines with the ammonia, forming phosphate of ammonia and disengaging carbonic acid with effervescence, while the phosphate of lime previously retained in solution by the excess of acid is precipitated. The sulphate of lime is at the same time decomposed by another portion of the carbonate of ammonia, carbonate of lime being thrown down, and sulphate of ammonia remaining in the solution along with the phosphate of ammonia. After filtering and concentrating the liquid by evaporation, the phosphate of ammonia crystallizes, still mixed with the sulphate of ammonia, and on melting these in a silver or platinum crucible, the sulphate of ammonia is volatilized, and the ammonia of the phosphate at the same time expelled. The phosphoric acid is melted, forming a transparent and colourless glass as it cools. In this state it has passed to the condition of metaphosphoric acid, and Berthier affirms that it still contains one-fourth of its weight of water.

390. If the solution of the superphosphate of lime be evaporated as it is procured at first, a solid substance is obtained, similar in appearance to the glacial phosphoric acid procured in the manner which we have just described; it is evident, however, that it must be contaminated with phosphate and sulphate of lime, and if the evaporation should be conducted in glass or earthen vessels, and the dry mass fused in an earthen vessel, it will contain a still greater quantity of impurities, as phosphoric acid acts both on glass and earthen vessels when its solution in water is concentrated, or when it is fused by exposure to heat. For many purposes where phosphoric acid is required, the solution of the superphosphate of lime may be employed instead of the purified phosphoric acid.

391. Phosphoric acid may be formed also by dropping very small pieces of phosphorus at a time into a vessel of platinum, as a crucible, filled half full of nitric acid, and continuing to add it till no more is dissolved ; the acid should be heated gently by a lamp or chauffer. The phosphorus takes oxygen from the acid, and a large quantity of binoxide of nitrogen is disengaged. The operation must be concluded with extreme care, to prevent any violent action taking place. When a sufficient quantity has been added, the phosphoric acid may be obtained in the solid form by evaporating the liquid to dryness, by which any traces of nitric acid or ammonia are completely expelled. The production of ammonia arises from the complete decomposition of a portion of water and of nitric acid, the hydrogen of the one combining with the nitrogen of the other, as the oxygen of both is removed by the phosphorus. By the action of the heat in evaporating it, the phosphoric acid passes to the condition of metaphosphoric acid.

392. The metaphosphoric acid, prepared as described in the preceding paragraph, and in 382 and 389, may be restored to the state of phosphoric acid by boiling it in water.

" 393. Phosphoric acid is sublimed by exposure to heat in close vessels, without losing the water that remains with it after fusion; and still more rapidly when heated by the open fire ; but when combined with a small quantity of an alkali or earth, it cannot be volatilized. It is very soluble in water and deliquescent, tastes extremely sour, but is not corrosive ; it reddens the vegetable blues. On neutralizing phosphoric acid by an alkali, it gives a white precipitate with salts of lead, and a yellow precipitate with nitrate of silver. It is not easily crystallized, and yields phosphorus when heated along with inflammable matter. It acts upon silica and most vessels containing this earth.

394. Arsenic has lately been observed in many specimens of phosphoric acid and also of phosphorus, and is supposed to have been derived from the arsenic in the sulphuric acid used originally in preparing it. It is frequently in the form of arsenious acid, when it may be detected in the usual manner by hydrosulphuric acid. (See Arsenic.) But when mixed with phosphorus it may be observed in the metallic form, or separated in this condition as a black powder, when a solution of the phosphorus in

diluted nitric acid is concentrated till the phosphorous acid is decomposed with the production of phosphureted hydrogen.

395. The substance formerly called *phosphatic acid,* formed by exposing phosphorus to a moist atmosphere, has now been found to be a mixture of phosphorous and phosphoric acids. ,

Sect. IV.—Phosphureted Hydrogen. ,

Symb. H^3P^2. *Eq. by W.* 34.4 = *Hydrogen* 3 + *Phosphorus* 31.4. *Eq. by volume* ⊞ *(two measures).*

396. This gas is prepared by exposing the crystalline compound of water and phosphbrous acid (377) to heat in a small retort, and collecting the gas that is disengaged over water. The oxygen of part of the phosphorous acid and of the water converts the rest of the acid into phosphoric acid, and the phosphorus that remains combines with the hydrogen of the water that is disengaged.

397. Another method of preparing phosphureted hydrogen consists in mixing hydrochloric acid diluted with several parts of water with phosphuret of calcium. For this purpose a small tubulated retort is filled nearly full with the acid liquid; fragments of the phosphuret are then put in, and the gas collected over the pneumatic trough. Phosphuret of calcium, indeed, decomposes water without the addition of an acid, and disengages phosphureted hydrogen gas; but it is procured more easily by adding the hydrochloric acid. In both cases, a portion of the water is decomposed, its oxygen combining with the calcium and forming lime, and the hydrogen uniting with the phosphorus.

398. Phosphureted hydrogen gas, in its purest form, is transparent, colourless, and not spontaneously inflammable at ordinary temperatures. It detonates with air or oxygen, however, when heated to 300°, or when the electric spark is passed through the mixture. If prepared with potassa or lime in the manner described in the following paragraphs, it is disengaged at first spontaneously inflammable. Professor Graham has also ascertained that it becomes spontaneously inflammable at natural temperatures, if mingled with from 1–10,000dth to 1–1000dth part of nitrous acid.

399. A third method of preparing phosphureted hydrogen consists in mixing small pieces of phosphorus with water and potassa or lime, and exposing the mixture to heat in a glass or metallic retort ; but it is not considered so pure when obtained in this manner. With lime the gas comes away slowly and steadily when it begins to be disengaged, but with potassa it is evolved much more rapidly, and more care is required in conducting the process. ' With a large quantity of water, the gas is long in coming, as the materials do not act upon one another till the most of the water has been expelled.

400. Forty grains of phosphorus, 50 of caustic potassa, and 60 drops of water, give this gas very readily when gently heated in a small retort (capable of holding an ounce and a half or two ounces when quite full) and with very little trouble. The water should be put in first, then the phosphorus in a single piece, and lastly the potassa, which produces considerable heat as it's dissolved. A spirit-lamp or gas-lamp will be found most convenient for heating the retort, as the temperature may be easily regulated by holding it at any distance that may be required. A slight explosion generally takes place in the interior of the retort, from the phosphureted hydrogen that is first produced reacting upon the common air in the retort ; and as considerable condensation takes place at the same time, if the beak of the retort be placed in the pneumatic trough before this is observed, water will be very apt to be thrown into it by the pressure of the atmosphere. The best method is to place the beak of the retort into a cup containing a very small quantity of water in the manner shewn in Fig. 71, page 48, not transferring it to the pneumatic trough till the vapours formed in the retort shall have been expelled, and the gas be transparent and colourless, which takes place almost immediately after the air in the apparatus has been acted upon by it. If the heat be applied very slowly at first, the oxygen of the air is gradually consumed. The beak of the retort used in all these experiments should be small, that neither air nor water may enter too quickly.

401. When a large quantity of this gas is required, it will be found convenient to prepare it by filling a green glass-retort (a metallic one is still better) with milk of lime and chips of phosphorus ; 75 grains of phosphorus with 1500 of slaked lime and three and a half or four ounces of water by measure will

give a sufficient quantity for the experiments which are usually performed with it.   A tin tube may be attached to the beak of the retort, if it is not sufficiently long.   After a considerable quantity has come over, a gas is disengaged, which does not take fire spontaneously ; the process may then be discontinued. When a metallic retort is used, it should be made of two pieces, similar to that represented by Fig. 22, page 13.   Gun-metal is much better than iron for this purpose.   It may be filled about two-thirds full, and heated by a chauffer, placing it on the cinders.

402. To shew the horizontal rings that are formed when this

Fig. 112.

gas takes fire in a calm atmosphere, which present a very beautiful appearance, the beak of the retort should be placed under water in the pneumatic trough, or in a glass basin. Every bubble of gas, as it breaks on the surface of the water, immediately takes fire, and produces a ring.
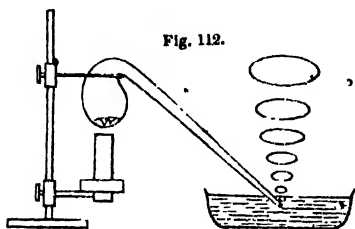
403. Place a jar half full of air on the shelf of the pneumatic trough, and allow one or two bubbles of the gas to rise in it ; a vivid flash of light is seen as before, and oxygen is consumed. The jar must be held firmly as the gas enters.

404. Place another jar half full of oxygen gas in the same situation ; each portion of the gas as it rises in the jar and mixes with the oxygen produces an extremely vivid flash of light, perhaps as intense, though only momentary, as can be made by artificial means.   In performing this experiment, care must be taken not to allow the gas to accumulate in the jar without mixing with the oxygen, which frequently takes place from the deposition of a film of phosphorus on the surface of the water.   This rises with the gas, and sometimes a large quantity gathers into a single globule, and whenever this breaks, the jar is thrown down or broken by the violence of the explosion.   To prevent gas accumulating in this manner, all that is necessary is to tap the jar with the finger when they begin to appear, or shake it gently over the shelf of the trough on which it is standing ; should they not explode immediately, the jar

must be removed at once from the pneumatic trough, and the air allowed to enter freely.

405. When mixed suddenly with one and a half times its volume of oxygen gas, it is all consumed, and a violent detonation takes place. Two strong jars containing the proper proportions of the gases must be employed for this experiment, and the one into which the gas is transferred should be more than sufficient to hold both the gases, and wider than the other : it is scarcely necessary to add that they must be mixed under water, and only a small quantity of the gases employed, about one or two cubic inches.

·406. A flash of light appears also, according to Dr Henry. when this gas is admitted into a flask exhausted of air as completely as can be done by the air pump, shewing that there is still a small quantity of air present. To shew this, a jar with a stopcock fixed to it is filled with the gas, or it may be only filled in part if it should be a large jar, and an exhausted flask, which must also be provided with a proper stopcock, is connected with it precisely in the same manner as the bladder is connected with the jar in Fig. 46, page 28. The stopcock of the jar is opened first that the phosphureted hydrogen may have time to act on the small quantity of air between the two stopcocks, and on opening the other, water is forced from the pneumatic trough into the jar by the pressure of the atmosphere, and the gas which it contained at the same time passes through the connector into the exhausted flask.

407. The products of its combustion, both in air and oxygen, are metaphosphoric acid and water. Experiments similar to those which have been described may be made by transmitting the gas into jars filled with chlorine, a brilliant green light being produced ; the chlorine combines with the hydrogen, and also with the phosphorus, forming hydrochloric acid and chloride of phosphorus. If a glass-retort be taken into a dark room while full of this gas, it presents a very beautiful appearance, as the atmospheric air gradually mixes with the phosphureted hydrogen.

408. Phosphureted hydrogen may be detonated with oxide or binoxide of nitrogen ; it is decomposed also by iodine and potassium, which combine with the phosphorus. Water absorbs about five per cent, according to Dr Thomson, when it

has been previously boiled to expel the air which it usually
contains ; solutions of the sulphate of copper and chloride of
calcium absorb it in large quantity, and are employed to
ascertain its purity, as they do not absorb any other gases
with which it might be mixed. Its smell is very fetid and
disagreeable.

409. Numerous interesting researches have been made in
reference to the compounds of phosphorus and hydrogen, by
Thomson, Dumas, Rose, and other chemists, but their history
has not yet been completed. The spontaneously inflammable
phosphureted hydrogen gas, and that not spontaneously inflam-
mable, have more recently been regarded as isomeric compounds.
From the researches of Leverrier, it is now considered,—

I. That the spontaneously inflammable gas consists of two
eqs. of phosphorus and two of hydrogen.

II. That the compound frequently termed perphosphureted
hydrogen consists of phosphureted hydrogen and a small quan-
tity, about 1-30th, of the spontaneously inflammable compound.

III. That the solid matter deposited from the gas prepared
with potassa or lime mixed with water and phosphorus, is a di-
hydruret of phosphorus, consisting of two eqs. of phosphorus and
one of hydrogen.

Sect. V.—Phosphuret of Sulphur.

410. Phosphorus and sulphur combine in all proportions, form-
ing a compound that is more fusible and inflammable than either
of these substances. It must be made with great caution, as an
explosion always takes place on heating its elements together,
arising probably from the presence of a little moisture, which
it is not easy even with every care to separate from them,
Thenard having observed a disengagement of hydrosulphuric
acid at the moment of combination, under whatever circum-
stances they may be presented to each other. The phosphorus
is believed to take the oxygen of the water as the sulphur com-
bines with the hydrogen.

411. The best method of preparing this compound consists in taking 10 or 20 grains of phosphorus, heating it in a test-tube about 8 inches long and half an inch in diameter, and adding the sulphur in small pieces at a time, not exceeding half a grain. The phosphorus must be made to boil briskly by a spirit-lamp immediately before each piece of sulphur is allowed to drop into it, and the effervescence arising from its action allowed to terminate before another piece is introduced.

412. In the ordinary way, if even a few grains of phosphorus and sulphur be heated gently together in a tube till fusion take place, the reaction is often so violent that the materials are thrown to a distance of several feet; the larger the quantity of moisture adhering to the sulphur or phosphorus, the more dangerous the action.

413. Liebig has formed a hydrated phosphuret of nitrogen by the action of solid chloride of phosphorus, with ammonia and water. See Phil. Mag. vol. vii. 1835.

CHAP. VII.—CARBON.

Symb. C. Eq. by W. 6·12; by volume □ *(one measure). Sp. gr. of Wood Charcoal* 0·441.

The DIAMOND *consists of Carbon in its purest form.*

CHARCOAL *consists almost entirely of carbon, but is mixed with any saline or earthy matter, which the wood from which it is prepared may contain.*

COKE *is the charcoal of coal, and contains carbon in a much denser form, and much less pure than the charcoal of wood.*

BONE BLACK *or* IVORY BLACK *is the charcoal procured by the decomposition of Bone or Ivory. It is frequently termed* ANIMAL CHARCOAL, *but some apply this term to charcoal obtained by heating other animal substances.*

PLUMBAGO *or* BLACK LEAD *is composed principally of carbon with a small portion of iron.*

COAL *is generally composed of carbon, oxygen, hydrogen, and*

nitrogen, mixed with iron, sulphur, and various saline and earthy substances.

SPLINT COAL *presents a splintery fracture.*

CAKING COAL *undergoes an imperfect fusion when heated, before it is reduced to a cinder.*

CHERRY COAL *has a slaty fracture, and is very easily broken.*

CANNEL COAL or PARROT COAL *gives a large quantity of gas, which burns with a rich flame, and is preferred for the preparation of coal gas.*

GLANCE COAL or ANTHRACITE, *consists almost entirely of carbon. It burns with a fixed light, little or no flame being evolved when it is heated.*

414. Though carbon has not been obtained in the gaseous form, so as to admit of experiments being made with it in this state, it may be volatilized by the action of a powerful galvanic battery, and it has been customary to represent its equivalent by volume by a measure equal to that of the equivalent of hydrogen gas. The term Carbon is used to signify the pure and inflammable part of charcoal, which, in the manner that it is usually procured always contains a small proportion of earthy matter.

415. Charcoal is prepared on the large scale by piling wood into cones, which are often of an immense size, covering it in a great measure with turf, and setting fire to it through a few air-holes, which are closed when it is properly kindled. It is also prepared in great quantities now, by exposing wood to heat in iron cylinders, for the manufacture of gunpowder, where a finer kind of coal, as it is technically termed, is required. A large quantity of inflammable gases, water, tar, and impure acetic or pyroligneous acid are disengaged; the latter is condensed in barrels connected with the cylinders, and purified by subsequent operations. Wood consists of carbon, oxygen, and hydrogen; and in both these processes the oxygen and hydrogen, and part of the carbon, are driven off by the heat, the different products that are disengaged being formed by these elements combining with one another. The greater part of the carbon remains, mixed with any saline matter that may have previously existed in the wood.

416. To prepare a small quantity of charcoal, a few pieces of

wood may be put into a crucible, covered with sand, and exposed to heat in the open air or in a furnace. When no more gas is disengaged, the crucible may be removed from the heat, but the charcoal must not be taken out till it is cold, to prevent it from taking fire. The wood (a potato does equally well) may be cut into the form of a crucible, or any other shape that the charcoal may be required to have.

417. Very pure carbon may be obtained by exposing several inflammable substances to heat in vessels where they are not, brought into contact with the air, as by passing the vapour of alcohol or turpentine through a red-hot tube ; a considerable quantity of carbon is deposited, in the form of a fine powder. The condensed soot that is obtained from the imperfect combustion of resinous substances, oil, tar, and other inflammable matters, and known by the name of *lamp black*, consists principally of carbon, in a very fine state of division ; and when exposed to a red heat for some time in a covered crucible, to drive off any volatile matter adhering to it, may be used for experiments where the purest carbon is required.

418. The charcoal obtained by the smothered combustion of coal, as that from the gas-works, is usually termed *coke*, and consists of that portion of the carbon which the hydrogen and oxygen have not been able to carry away in the gaseous form, mixed with saline and earthy matter which the coal contains.

419. Charcoal usually retains the form of the wood from which it is prepared. It is black and brittle, insoluble in water, and has the property of destroying the odour, the taste, and the colour of many substances, from which it is much employed in the arts, and for domestic purposes, as in rendering tainted meat fresh, &c. By filtration through charcoal powder, water that has turned putrid from being long kept in wooden vessels becomes sweet and palatable.

420. On the small scale, it is often used with great advantage in depriving of their colour solutions which are to be chemically examined. For this purpose, *animal charcoal*, termed also *ivory black*, is usually preferred, which is a mixture of charcoal and phosphate of lime, prepared by exposing bones to heat in close vessels. The charcoal is derived from the decomposition of the animal matter of the bone.

421. By exposing it to a red heat in close vessels, after it has

been employed in decolorizing processes, or for removing offensive odours, it will be rendered again fit for use, and thus the same portion of charcoal may be employed repeatedly.

422. Charcoal is infusible by heat, and undergoes little or no change in its appearance or properties when exposed to heat in close vessels ; but when subjected to the action of a powerful galvanic battery, part of it is volatilized, and the lustre of the remainder is increased, while it also becomes so hard as to be able to scratch glass. It approaches in no small degree, therefore, in its character to the diamond, which is composed of pure carbon, and produces the same compound (carbonic acid) during its combustion.

423. When charcoal has been recently prepared, it has the property of condensing in its pores large quantities of different gases, without any other changes taking place in their condition or its own. The following table by Saussure, shews the quantity of different gases which boxwood-charcoal absorbs, when allowed to remain in contact with these different gases for twenty-four hours.

Ammonia, ... 90 vols.	Carbonic Acid, . 35 vols.
Hydrochloric Acid Gas, 89	Oxygen, . . . 9.25
Hydrosulphuric Acid, 65	Nitrogen, . . . 7.5
Oxide of Nitrogen, . 40	Hydrogen, . . . 1.75

424. Charcoal is highly inflammable, producing great heat during its combustion, and is much employed as fuel, especially where smoke must be avoided, as it gives no flame nor soot when properly prepared. In oxygen gas it burns more brilliantly than in atmospheric air, producing vivid sparks ; the apparatus already described for the combustion of charcoal in oxide of nitrogen, Fig. 74, page 50, may be used. In both cases, the product of the combustion is carbonic acid. The oxygen neither increases nor diminishes in volume, but becomes heavier by the quantity of carbon which combines with it ; every 16 parts of oxygen take up 6.12 of carbon.

425. Even the diamond, the hardest substance in nature, may be inflamed in oxygen gas ; carbonic acid is the only product of its combustion. It was in this manner that its real nature was ascertained, though Newton conjectured that it was an

inflammable substance long before the experiment was made, from its great refractive power.

426. Expose some well pounded charcoal to a red heat in a covered crucible, remove it, and then drop some nitric acid upon it from a pipette with a long stem. The charcoal takes oxygen from the acid, and a shower of sparks is thrown out. Charcoal, in a minute state of division, decomposes this acid at a much lower temperature.

427. The charcoal procured from different varieties of wood, burns with various degrees of facility according to the texture of the wood, and the heat employed in preparing it. The lighter and more porous, and the lower the temperature with which it may have been prepared, the more readily does it enter into combustion. It is not considered-desirable to heat it always till it becomes black ; in the finest kinds of gunpowder, the charcoal always presents a brownish shade, which may be easily seen on bruising a little on some white paper. In this condition, it is probable that the volatile matter in the wood has not been entirely expelled.

428. Many varieties of coke, prepared at a high temperature, and containing iron and other impurities, often present a vitrefied appearance, assuming a leaden colour, and refusing to burn in an open fire. The anthracite, a variety of coal resembling coke in being composed principally of carbon, presents the same peculiarities ; but if these be heated in a furnace where a greater heat is produced than in a common fire, they burn for a long time, and produce a very high temperature.

429. All carbonaceous substances, whether they are consumed with facility or not in a common fire-place, may be deflagrated on heating them with nitre, a mode often resorted to with the view of proving the presence of carbon. Take one or two grains of coke that does not burn in an ordinary open fire, reduce them to a fine powder, mix them with thrice their weight of nitre, and heat the mixture in a green glass-tube, held in the flame of a lamp. The mixture should not occupy more than a quarter or half an inch of the tube in depth. The carbon receives oxygen from the nitric acid of the nitre, and produces carbonic acid, which combines with the potassa and forms carbonate of potassa.

430. Dissolve the residuum in water, filter, and let the filtered liquor drop into lime water : a turbidity is immediately induced

as the carbonic acid unites with the lime and forms carbonate of lime.

431. Many animal and vegetable matters, when heated, leave a very hard carbonaceous crust, difficult of incineration. If it be heated with nitre, however, it is consumed in the same manner as the powdered coke.

432. Should the coke or other carbonaceous matter fused with the nitre, contain any iron or earthy substance, it, in general, remains on the filter after the carbonate of potassa has passed through in solution.

433. From the powerful affinity which charcoal has for oxygen at a high temperature, it is employed for deoxidating many metallic ores, and other substances. With this element it forms two important compounds, carbonic oxide and carbonic acid. It unites with hydrogen in several proportions, and with nitrogen it forms cyanogen, the base of hydrocyanic acid. It enters into the composition of all the products of the vegetable and animal kingdoms. It is used in the preparation of steel, in the composition of gunpowder, and forms the basis of black paints and printing ink.

Sect. I.—Carbonic Oxide.

Symb. O C, *or* ·C. *Eq. by W.* 14.12; *by volume* [1] *(one measure).* *Sp. gr.* 0.973. *W. of* 100 *c. i.* 30.186 *grains.* 100 *c. i. of water absorb* 1.56 *of this gas.*

434. There are several processes by which this inflammable gas may be procured, most of which consist essentially in depriving carbonic acid of half its oxygen by heating it with some substance which has a great affinity for this element. The most convenient method is to heat crystallized oxalic acid with aqueous sulphuric acid in a retort, collecting the gases evolved at a pneumatic trough filled with lime water; 500 grains of oxalic acid and six or eight drams by measure of sulphuric acid, give a large quantity of gas. The heat must be applied cautiously, to prevent the disengagement of gas from going on too quickly. The retort should not be filled more than a third full. A much larger quantity of sulphuric acid

may be employed, and the gas is then very rapidly evolved. In this process, the aqueous sulphuric acid withdraws the water of crystallization from the crystallized oxalic acid. But dry oxalic acid consists of two eqs. of carbon and three of oxygen, and when the water of crystallization is withdrawn, these are resolved into carbonic oxide and carbonic acid gases. The lime combines with the carbonic acid as the gases are discharged at the pneumatic trough, the water becoming milky as the carbonate of lime thus formed is precipitated. The carbonic oxide is left (439). If the gases be collected at the mercurial trough, and caustic potassa be introduced into a tube or jar containing the mixed gases, the carbonic acid is removed by the potassa. The carbonic oxide which remains is exactly equal in bulk to the carbonic acid condensed.

Symb. $:C^2 = \circ C$ & $:C$.

435. Another method is to expose dried chalk to heat with an equal weight of iron-filings in an iron tube-retort, raising its temperature speedily in a good furnace or open fire, till the gas begins to come. The materials should be reduced to as fine a state of division as possible, and the temperature must never be allowed to fall, otherwise the gas soon ceases to come, or carbonic acid is disengaged instead of carbonic oxide. Any of the iron retorts represented 'in the chapter on oxygen will do very well for preparing this gas.

436. In this process, the chalk (which is a carbonate of lime) parts with its carbonic acid on exposure to heat, and the iron mixed with it takes away one equivalent of oxygen, thus reducing the carbonic acid to carbonic oxide. Charcoal may be used instead of iron, and occasionally they are employed together, but unless the charcoal be freed completely from water and hydrogen, the carbonic oxide that is then procured will be contaminated with carbureted hydrogen. By mixing a small portion of charcoal with the iron-filings and chalk, the residuum of the operation is extracted much more easily from the apparatus in which they are heated. A sufficient quantity of gas for shewing the general properties of carbonic oxide may be procured from 250 grains of chalk.

437. Another process for preparing carbonic oxide gas consists in transmitting carbonic acid repeatedly over carbon at a high temperature in a porcelain tube. It should be sufficiently

long to allow corks to be put in at both ends without any danger
of their being destroyed by the heat when it is made to traverse
a furnace.   The tube is to be stuffed with fragments of char-
coal ; a bladder with a stopcock, half full of carbonic acid, is
then fitted to one of the corks by boring a hole through it, and
an empty bladder to the other.   When the charcoal has been
properly heated, taking care not to urge the heat too strongly
at first lest the tube should be cracked, the carbonic acid is
passed slowly over the charcoal from the one bladder to the
other by pressing it gently, and this is repeated several times.
The volume of the carbonic acid is doubled, and it is converted
entirely into carbonic oxide.   Carbonic oxide is procured more
easily by the methods previously described.

438. The theory of the action is sufficiently obvious ; the
carbonic acid is converted into carbonic oxide by losing one
proportion of oxygen, as is seen in the following diagram, and
this, combining with part of the carbon, also becomes carbonic
oxide.   But carbon occupies the same volume whether combined
with one or two equivalents of oxygen ; consequently, a given
measure of carbonic acid must double its volume when converted
into carbonic oxide by carbon.

Materials.	**Fig. 113.**	*Products.*
22.12 Carbonic Acid, { Carbon 6.12		14.12 Carbonic Oxide.
{ Oxygen 8		
{ Oxygen 8		
6.12 Carbon 6.12		14.12 Carbonic Oxide.

Symb. C & :C = 2 ·C.

439. When carbonic oxide is required particularly pure, it
ought always to be agitated with lime-water or a very dilute
solution of caustic potassa, to remove the small quantity of car-
bonic acid which it generally contains, by whatever process it
has been prepared.

440. Carbonic oxide is an inflammable gas, transparent and
colourless, and burns with a pale blue and lambent flame.
During its combustion it combines with half its volume of oxy-
gen, and is converted into carbonic acid ; a condensation taking
place equal to the volume of oxygen consumed.   It detonates
feebly with pure oxygen, even when mixed in the exact pro-
portion required for converting it into carbonic acid.   It is very
noxious to animal life.

SECT. II.—CARBONIC ACID.

Symb. Q²C, or :C.   *Eq. by W.* 22.12 (*oxygen* 16 + 6.12 *carbon*);
by volume □ ; *sp. gr.* 1.524; *W. of* 100 *c. i.* 47.283 *grains.* 100
c. i. of water absorb 100 *c. i. of this gas.   It is gaseous at all
temperatures to which it has hitherto been exposed under ordinary
pressure, but has been rendered liquid by a pressure of thirty-six
atmospheres.*

441. Carbonic acid is most easily procured by pouring hydro-
chloric acid diluted with an equal bulk of water on fragments
of white marble, a compound of carbonic acid and lime.   The
hydrochloric acid combines with the lime, and the carbonic acid
is disengaged with effervescence.   The materials may be put
into a retort, or a bottle or flask with a bent tube adapted to it
may be employed, as no heat is required ; the gas is collected in
jars over the pneumatic trough.   Two parts of hydrochloric
acid (sp. gr. 1.18) by weight may be taken for every part of
marble.   As 100 grains of marble contain 44 grains of carbonic
acid, which occupy very nearly the space of 100 cubic inches at
ordinary temperatures, it is easy to calculate the quantity of
marble required to afford a given bulk of gas.

442. Carbonic acid is a transparent and colourless gas, heavier
than air, and incapable of supporting combustion or respiration.
Animals are asphyxiated immediately when they breathe in an
atmosphere of this gas, and life is soon altogether extinct if
they be not speedily removed to the air.   Hence the fatal acci-
dents which occur in old wells and pits, at the bottom of which
it often accumulates in considerable quantity.   A burning
candle, therefore, should always be let down before any person
descends, which will be extinguished if the air is loaded with
this gas, and incapable of supporting respiration.   It must not
be forgot, however, that there are instances where individuals
have soon become insensible, from the action of this gas, in an
atmosphere not sufficiently loaded with it to prevent the com-
bustion of a candle.

443. An oil-lamp burns in general more powerfully than a
candle, and may be seen in constant use in mines containing

air so vitiated with carbonic acid that it cannot support the combustion of a candle.

444. From its great specific gravity, carbonic acid gas may be poured from one jar into another in the same manner as water ; and a jar left full of it, with the cover off and the mouth turned upwards, will retain it for a considerable time. A candle may be extinguished also by pouring the gas upon it, and the experiment may be varied in many different ways.

445. Pure carbonic acid does not pass into the lungs when it is attempted to inspire it, a spasm of the glottis which immediately takes place preventing its entrance ; but if it be diluted with a considerable quantity of air, it then passes freely into the lungs, and though its action is scarcely perceptible at first, it soon gains upon the system, and has often proved fatal in a close apartment where a charcoal chauffer has been used.

446. Water absorbs its own volume of carbonic acid gas or rather more, and by pressure it may be made to take up a much larger quantity. A solution is easily made by filling a bottle about two-thirds full of the gas over the pneumatic trough, and shaking the remaining water with it as long as it continues to absorb any. It may be kept for years if put into bottles which are filled quite full and properly secured.

447. Carbonic acid water is sometimes prepared on the small scale by passing the gas through water in the bottles of Woulfe's apparatus, page 90. Another apparatus, invented by Dr Nooth
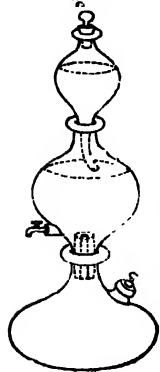
Fig. 114.

(Fig. 114), is also occasionally used for this purpose. It consists of three glass vessels, which are made to fit accurately to each other by grinding. In the lower vessel, the carbonic acid is prepared from a mixture of equal weights of sulphuric acid and chalk, the acid being previously diluted with twelve times its weight of water. The apparatus is inclined to one side, by a small piece of wood placed below it, that all the chalk (which should be finely powdered) may not mix with it at once. The middle vessel is filled with the water to be impregnated with the gas, a valve at the bottom allowing the carbonic acid to rise into it from the lower vessel, when it is accumulated in sufficient quantity to overcome the pressure of the liquid above, but constructed so as to

prevent any of the solution from falling into the lower vessel. When the gas accumulates in the middle vessel, it presses upon the surface of the liquid, a part of which is forced into the vessel above ; and when the whole water has been completely saturated, the excess of carbonic acid, after passing into the upper vessel (which always takes place whenever the level of the liquid falls below the extremity of the tube part of the upper vessel, as is represented in the figure), lifts up the conical stopper at the top, which returns to its place the moment it has escaped.   Before using it, the valve should be examined to ascertain that it moves readily on blowing through it.

448. Carbonic acid water has a pleasant acidulous taste, sparkles when poured from one vessel to another, but loses its agreeable pungency when exposed to heat, or to the air for some time, from the acid gas escaping.   This also takes place when it is frozen, or placed in the exhausted receiver of an air-pump.

449. Pour a little of the infusion of litmus into some carbonic acid water ; it is immediately reddened ; by boiling it for a few minutes the original colour is restored.

450. Mix another portion with some lime-water in a glass ; it immediately becomes milky, carbonate of lime being formed, which is insoluble.   Add an additional quantity of the acid water, and the liquid becomes clear, as a bicarbonate of lime is then formed, which is soluble.   If it now be exposed to heat, the excess of carbonic acid is disengaged, and it again becomes turbid.

451. Pour some lime-water on a flat plate, and expose it to the air ; a pellicle is speedily formed on its surface, from the carbonic acid in the air combining with the lime.

452. Blow air from the lungs through some lime-water in a bottle by a bent tube.   The carbonic acid produced during respiration combines with the lime, and renders the liquid turbid.

453 Fill a tube, about 12 or 18 inches long, with car- Fig. 115. bonic acid gas over the pneumatic trough ; close it with the finger or thumb, and place it in a small cup of mercury, or on the shelf of a mercurial trough.   Introduce a small quantity of a strong solution of caustic potassa from a pipette of the form represented in Fig. 115, by blowing upon it, taking care not to allow any air to enter.   If the carbonic acid be quite pure, the potassa absorbs it all,

carbonate of potassa being formed, and the mercury rises in the tube. If any common air be mixed with it, the bulk of the remaining gas indicates the quantity, and deducting this from the total amount of gas, the remainder gives the quantity of carbonic acid which it contained.

454. Carbonic acid combines with the different salifiable bases, forming a very well defined class of salts. It has, however, but a feeble attraction for them compared with almost all other acids, and may be easily displaced, assuming at the same time the gaseous form, when it is not retained in solution by a large quantity of water. The carbonates accordingly effervesce with most other acids, and by noting the quantity of carbonic acid disengaged in this manner, the quantity of carbonates in any saline mass may be estimated. This may be done either by measuring the volume of carbonic acid, which a given weight of mixed salts affords, or by ascertaining its weight.

455. In the first case, the easiest method of proceeding is to fill a long tube (closed at one end, and capable of containing two or three cubic inches) nearly full of mercury, filling it up afterwards with hydrochloric acid diluted with an equal quantity of water. The thumb is placed over this, after dipping it in oil, or rubbing it over with a little gas-lute, the tube inverted, and placed in a cup of mercury. One or two grains of the solid salt are then introduced into the tube (the experiment is most easily performed with a fragment of some carbonate), and the moment it rises to the top, and comes in contact with the acid, the carbonic acid is disengaged with effervescence, depressing the mercury. The amount of gas is estimated by examining the volume which it occupies and making the usual corrections; one equivalent of carbonic acid indicating one equivalent of a carbonate, whatever may be the nature of the base.

456. In the other method, which is more generally adopted, a thin glass flask or bottle, of the form shewn in Fig. 116, is placed on one of the scales of a balance with some hydrochloric acid, and, along with a given weight of the substance under examination, and the bent tube passing through the cork which fits to the mouth of the flask, accurately counterpoised. This tube is put in when the acid and carbonates are mixed together, to prevent any loss from particles of liquid that are thrown up
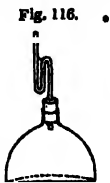
during the effervescence. Instead of a bent tube and a cork, the
mouth of the flask may be obstructed with some cotton wool,
which equally prevents any loss of the liquid, and allows the
carbonic acid to escape.   When the effervescence ceases, by
adding weights to the scale on which the glass vessel is placed
till it is again counterpoised, they will indicate the quantity of
carbonic acid that has been evolved ; before weighing it the
second time, the cork and tube should be taken out till the car-
bonic acid gas in the interior has been blown out gently by a
pair of bellows.

457. All bicarbonates (salts containing two equivalents of
acid with one of the base) are decomposed when heated to 212°,
or even with a less elevated temperature ; the excess of carbonic
acid being expelled, and a carbonate left.

458. Carbonic acid exists abundantly in nature, especially in
combination with lime, forming $\frac{44}{100}$ of every pure variety of car-
bonate of lime.   In the Grotto del Cane, and some other natu-
ral situations, it flows out in a continued stream in the gaseous
form.   It constitutes the characteristic ingredient of the carbo-
nated mineral waters, and is formed in large quantities by the
respiration of animals, during combustion and fermentation, and
by those changes which dead vegetable and animal matter are
continually undergoing at the surface of the earth.   It is gene-
rally supposed that carbonic acid is prevented from accumulating,
and the purity of the atmosphere maintained, by the vegetable
world, the leaves of plants decomposing carbonic acid in the
sunshine and exhaling oxygen. ' In the shade, however, they
absorb oxygen, and produce carbonic acid.

Combustion of Carbon in Fire-Places and Furnaces.

459. When carbon is freely supplied with oxygen, carbonic
acid is always produced.   But when the bed of cinders or of
charcoal is of considerable thickness, the oxygen of the air being
exhausted in a great measure at the first layer of fuel it comes
in contact with, the carbonic acid rises through the superincum-
bent carbon, and is decomposed by it, carbonic oxide gas being
formed by the carbon abstracting part of the oxygen of the car-
bonic acid, while another portion of carbonic oxide is evolved
as the first eq. of oxygen is withdrawn.   But the two eqs. of

carbonic oxide thus formed burn freely with a pale blue flame when they come in contact with the air at the top or front of the fire, and combining with oxygen, they produce ultimately two eqs. of carbonic acid. By studying the symbolical 'expression of these changes, they will be easily understood.

I. C & 2 ·N² = :C & 4 N.   Carbon and two of air produce carbonic acid and 4 of nitrogen.

II. :C & C = 2 ·C.   Carbonic acid and carbon produce two of carbonic oxide.

III. 2 ·C & O² = 2 :C.   Two of carbonic oxide and two of oxygen produce two of carbonic acid.

460. The blue flame produced by the combustion of the carbonic oxide is most distinctly marked in cold frosty weather, when the air is dry ; but in summer, when the air is charged with much more moisture than in winter, the flame is less marked, the hydrogen of the watery vapour forming carbureted hydrogen, which burns with a different hue.

461. The intensity of the heat produced by the combustion of carbon is much influenced by its purity and state of aggregation, the quantity consumed within a given time, the construction of the fire-place or furnace in which it is used, and the manner in which the air is supplied. In all ordinary fire-places and furnaces, the *draught* or velocity with which the air is propelled in the chimney depends upon the degree to which it is expanded, and the height of the column of expanded air. The greater the expansion (that is, the greater the difference between the specific gravity of the external air and that of the air in the chimney), and the higher the column of expanded air,—the greater the velocity of the movement, the greater the consumption of fuel within a given time, and the more intense the temperature. Few subjects are of more importance to the practical chemist than the movements induced in aërial fluids, so far as they depend upon alterations of temperature, and the following figures on this subject should be carefully studied by the beginner till he is quite familiar with them.

462. When a fire is kindled in the open air, the fuel heats and expands the air in contact with it, and this rarefied air being no longer able to resist the pressure of the denser atmosphere by which it is surrounded, the latter rushes in on every side and pushes up the warmer air. Each successive portion of

cold air becomes rarefied as it advances to the source of the heat, and is pushed up in its turn, and this movement continues so long as an inequality of temperature is sustained. The real cause, then, of the draught or movement of air in a chimney, is the pressure of the colder and heavier external air upon that expanded by heat and within the chimney, a continual current taking place so long as there is any fuel to maintain an elevated temperature.

FURNACES, FIRE-PLACES.

463. If a fire be kindled in the middle of a room, Fig. 117, the door, windows, and chimney, being completely closed, the air at the fire-place expands, and becomes lighter, bulk for bulk, than the rest, which descends and flows under it, pushing it upwards in the same manner as water poured into any vessel with a cork at the bottom, sinks under the cork, and floats it as the liquid insinuates itself below it. A perpetual circulation thus goes on so long as the heat is continued, all the air being in time involved in this movement, cooling and sinking on the exterior, while fresh quantities are continually expanding as the heat affects them.*
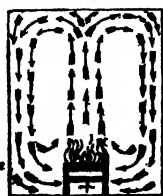
Fig. 117.   Fig. 118.   Fig. 119.

464. If a fire be kindled in an apartment or chimney, close below but open above, a current of warm air will ascend, the cold air descending at the sides and forcing it up, so that the air will be continually renewed ; see Fig. 118.

465. When a fire is heated in a chimney open below and above, the air moves quickly, the warm air in the chimney being pushed up rapidly by the external colder and heavier air, Fig. 119.

* This and the following paragraphs on the movement of air, &c., are taken from my Rudiments of Chemistry.

466. When two chimneys are connected together by a flue, Fig. 120, and a fire kindled in one of them, the air ascends in the one with the fire, being pushed upwards by the cold air which descends through the other. A similar arrangement is frequently adopted in ventilating mines ; the horizontal part of the figure may represent that part of the mine which is worked, and the perpendicular portions the two shafts which lead to the mine, the air descending in the one and rising in the other.

467. In Fig. 121, the currents are represented as they occur in a common fire-place. Air enters by the doors or windows.

468. Fig. 122. illustrates the currents in a furnace. There, the space left open in a common fire-place being closed, a more intense heat is produced, as no air escapes into the chimney which does not pass through, the fuel and contribute to the combustion, so that the column of air in the chimney is more expanded (461).

Fig. 120.

Fig. 121.

Fig. 122.

469. That the fuel may be supplied with air, and the foul air be removed, fresh air must have free access to the apartment.

Fig. 123.

When, the doors and windows fit so tightly as not to admit of this, then some aperture must be made for this purpose alone. Fig. 123, represents a mode which has been occasionally adopted for this purpose, one chimney leading in a descending current of fresh air, while by the common chimney it is carried away.

470. When air is not admitted by this or some other arrangement, cold air descends in the chimney, entangling and carrying down some of the ascending warm and smoky air, and in such cases the room will necessarily smoke ; two currents may be seen in such vents, Fig. 124, which are perpetually affecting each other.
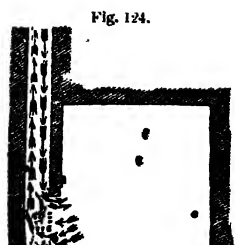
Fig. 124.

Fig. 125.

471. In stoves, Fig. 125, heated air is frequently produced by allowing cold air to enter between the inner case containing the fuel and the outer case ; the air is warmed as it passes, and may be conveyed by pipes to a distant apartment.   The smoke is led into a chimney by a separate pipe.

472. If heated air be introduced by thousands of small apertures in the floor of any apartment, from a chamber where it is previously heated to the required temperature, it will ascend in a continuous stream when the external air is colder and heavier, as in Fig. 126.   In warm weather the currents would not be sufficiently under our control, as the air in the

Fig. 126

interior might then be frequently of the same temperature, or even colder than the air in the exterior.
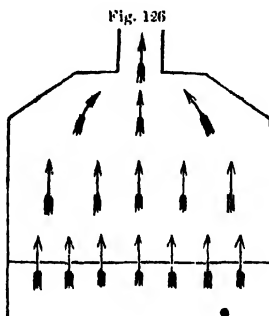
473. Large public buildings may be ventilated in the manner represented in Fig. 127. The air in the chimney having been heated powerfully and much expanded by the furnace k, cannot resist the pressure of the colder external air, which therefore pushes it upwards, and is forced in the same course in its turn : fresh air accordingly descends in the other chimney, as by a, b, c, passes through the apertures in the floor, and rises in a slow but constant stream to the roof, whence it is conveyed to the chimney.   Doors are placed so as to allow the rapidity of the current to be regulated according to the quantity of air required.   A power may thus be obtained capable of operating to

Fig. 127.
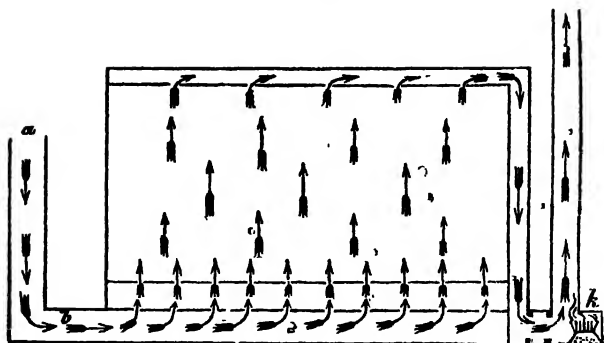
any extent, and so completely under control that it can be adapted to the varying circumstances in which it may be applied, while it can also be easily regulated, and diminished or increased, in an instant with the utmost precision.   It will also act upon air although previously heated or cooled through the whole range of temperature observed at the surface of the earth.   By kindling the fire in *a*, instead of at *k*, the course of the currents is entirely reversed.

474. In a common fire-place, heat is communicated principally by radiation, the smoke and consumed air ascending in the chimney.   The less the quantity of metal, the greater the heat projected into the room.   With large metallic bars and plates a great quantity of heat is continually withdrawn by conduction, as the air which passes by them ascends in the chimney.   Sometimes polished brass plates are used with advantage at the sides of particular fire-places to reflect into the apartment any radiant heat which may fall upon them.   Grates are almost invariably placed too high ; the branders supporting the fire should be on a level with the floor, and the ash-pit sunk below them.

475. Figs. 128 and 129 represent some of the principal flues and furnaces attached to the large chimney in the centre of my class-room, and the manner in which they enter in on every side, above and below ground.   In some extensive manufacturing establishments, a great number of furnaces often play into a single chimney.

476. To the right in Fig. 128 a SMITH's FORGE is first observed, then a REVERBERATORY FURNACE where the flame passes over the material to be heated, and then another furnace for

Fig. 128.
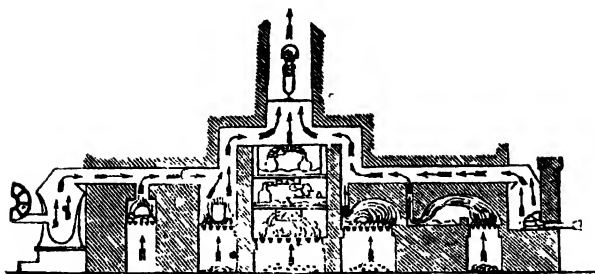
Fig. 129.
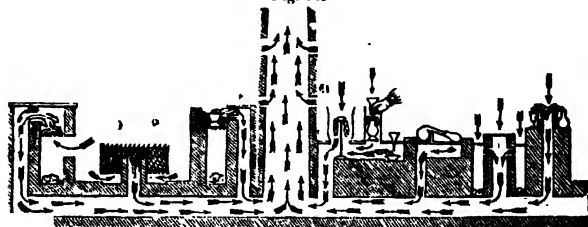
miscellaneous operations.   Below: and in the middle, a furnace
is placed to heat the superincumbent iron sand-bath plate, eva-
porating basins being put there, while noxious fumes are carried
away by the aperture represented.   Above is another plate of a
similar form, from which a more moderate heat is procured.   A
glass is also represented resting on a projection, and before an
aperture in the chimney, so that offensive gases from it are
rapidly withdrawn.   To the left, the first furnace observed is
used for operations where an intense heat is required ; the large
open space above the fuel allows all the consumed air to escape
with rapidity, and fresh air to enter.   A furnace with an earthen
vessel called a Muffle is next seen ; it is used in refining gold
and silver.   A blast furnace for melting iron is observed at the
extreme left ; the air, instead of entering through furnace bars,
being propelled by a fanner turned two thousand times a minute
by a steam-engine.

477. In Fig. 129 another section of the same chimney is
shewn, illustrative of the arrangements adopted in several of
the furnaces with descending flues, and of the manner in which
fumes are carried off in numerous operations where the pheno-
mena could not otherwise be so easily shewn without injury to
the operator and those around him.

478. On the extreme right four apertures are seen for this purpose, which are used with different kinds of apparatus. The retort which follows rests upon a few cinders mixed with charcoal, the air descending as in the other flues, while the receiver is kept cold by the rapid current of air descending on every side. In the next figure the experimenter is supposed to be introducing antimony or arsenic into a vase of chlorine surrounded by a glass chimney. Adjoining the tall chimney there is a large glass ventilator used for numerous experiments; naphtha is represented burning in a cup, the flame descending upwards of 12 or 18 inches. On the left hand, two furnaces are seen, well adapted for shewing some crucible operations which require to be watched as they advance, and between them is observed a section of the circular fire by which the practical class-room is heated; it is about 3 feet in diameter, with a circular vent in the middle about 10 inches in diameter, which carries away the products of combustion; with a less powerful chimney than that into which it plays, the diameter of the vent would require to be 2 or 3 inches greater. Coke is usually employed in this fireplace, and the chimney is generally concealed from view by a wreath of blue flame, which descends within it, being produced by the combustion of carbonic oxide, formed as described in par. 459.

479. Fig. 130 is an enlarged view of the descending ventilating apparatus seen immediately on the right of the large chimney in Fig. 129. It consists of a large glass cylinder open above and below, in the centre of which a portion of naphtha is represented in a state of combustion, the flame being carried down perpendicularly till it reaches the flue, and mixed with a large quantity of black smoke. The quantity of fumes carried off by any ventilating aperture
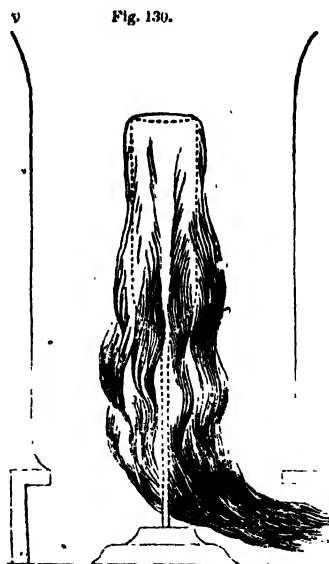
Fig. 130.

must depend upon the power of the chimney, and its area be
regulated accordingly. The cylinder may be made of tin or iron
instead of glass, where the object may be merely to ventilate,
without shewing any of the phenomena that may present them-
selves during the progress of the experiment.

480. If a single furnace be required, perhaps none will be
found more generally useful than that represented in Figs. 131
and 132. · It is of a form extremely convenient for numerous
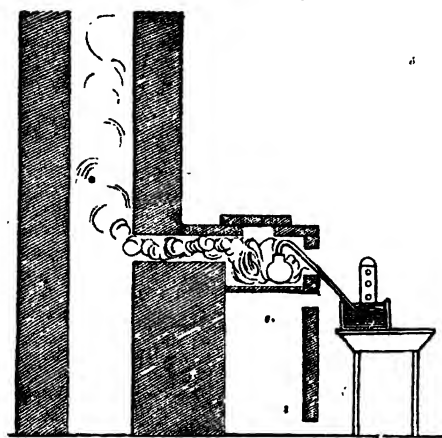
Fig. 131.   Fig. 132
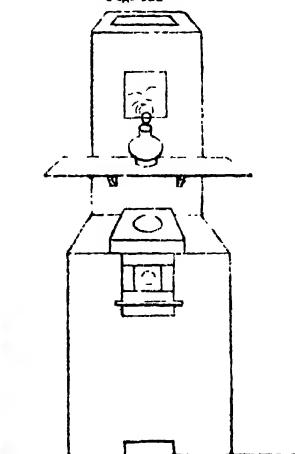
operations; and, where the vent is exposed on every side, other
furnaces may be placed around it. The area for the fuel may
be made from 9 inches to a foot square, and the horizontal chim-
ney 5 to 6 inches in diameter. In the section, Fig. 131, it is
shewn in use, an iron apparatus for the preparation of oxygen
on the small scale being placed in it. A front view is given in
Fig. 132, to shew the manner in which the bricks are arranged
in small pieces, so as to be taken out and adjusted according to
the experiment to be performed. The chimney works well when
it is 9 or 10 inches square, and about 10 or 20 feet high. A
shelf is placed below an aperture in the chimney ; and when
it is required to carry off fumes from any mixture, the vessel
is placed in the same situation as the flask, Fig. 132, the plug
being removed from the aperture, which is at other times closed.

481. Another form is sometimes adopted, Fig. 133, where it
is not necessary to adapt it for iron bottles with attached tubes

for the preparation of oxygen and other gases. If the flue be carried from 10 to 20 feet high, or be led into another chimney, it produces great heat. The numbers express the size in inches.

Fig. 133.
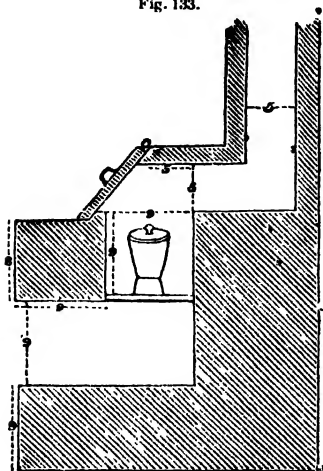
Fig. 134.
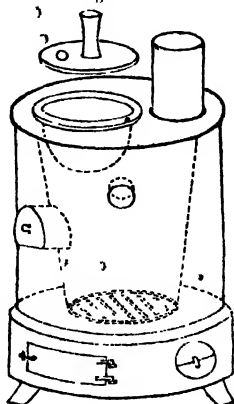
482. Dr Black's portable furnace, Fig. 134, is much used, and consists of a case of stout sheet-iron lined to the thickness of two or three inches with a very infusible clay or earthy composition. Above is an aperture,for an iron-pot to contain sand, and other openings may also be observed for introducing tubes and different kinds of apparatus. The pipe carrying away the smoke must be prolonged, or connected with a chimney.

483. In many cases, when noxious gases are disengaged during an operation that must be continued for some time by the application of heat, they may be carried away conveniently in the following manner. Connect a tube, expanding into a funnel-shaped vessel, with the upper part of the chimney through which fuel is usually introduced, in the manner represented in the adjoining figure (135). All noxious vapours are carried away by the chimney through this temporary apparatus. The power of the furnace is diminished considerably,

Fig 135.
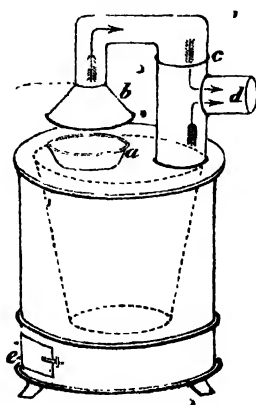
however, by this arrangement, and hence the tube is occasionally made to take another direction, opening into the ash-pit of the furnace in the manner represented by the dotted line. If we suppose the heat to be applied to the materials employed in an evaporating basin placed over the furnace, and the ventilating tube to follow the course of the dotted line, being fitted tightly to the furnace door, so that the furnace is supplied with air solely from the surface of the basin where the noxious fumes may be escaping, these, accordingly, are made to pass through the red-hot cinders. The fumes so generally evolved during the action of metals on nitric acid, and in many other operations are thus decomposed and rendered comparatively or entirely innoxious, even after they shall have escaped into the external air.

484. Dr Arnott has lately shewn that three-fourths of the heat produced in a common fire-place are wasted or carried away by the chimney, and has proposed to employ an earthen-ware furnace inclosed in an iron box, so that a much larger portion of heat shall be obtained from the fuel, apertures being made in the iron chamber to regulate the currents of air. A great saving of fuel has been effected in this manner. A self-regulating apparatus is attached to the furnace by which the admission of air is regulated so as to maintain it at a uniform temperature.

485. In the arrangement adopted by Mr Adams of Falkirk for heating any apartment, the fuel is economized, and the ventilation effectually secured. Cold air descends by a (Fig. 136),

Fig. 136.
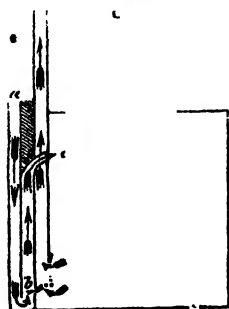
and is heated by coming in contact with the 'back' of the grate in the air chamber b : from it a small portion is allowed to enter near the fire by numerous openings, and the rest passes into the apartment along the floor ; or, where this cannot so conveniently be done, it may be introduced above as at d, or at a little distance from the chimney. It is obvious, however, that it is not necessary that any of the air should pass directly from the air-chamber to the fire-place ; if all of it be made to pass into the room, it must soon find its way into the fire-place, from the expansion produced there as the combustion proceeds.

486. With a few bricks, and a few small slips of narrow hoop-iron, a chauffer or small furnace may be constructed in a few minutes, capable of giving a good red heat, where the usual facilities for operating are not to be obtained, and where a common fire is not accessible. Suppose the bricks to be five inches broad and ten long, three are laid side by side as in Fig. 137, and three more in the same way, and opposite to the first, at the distance of four inches. The slips of iron are placed in the middle to support the fuel, and one or two courses of bricks laid above them, so as to leave an aperture five inches square. If the bricks be laid with mortar or clay, the current of air will be still stronger, and the heat greater. By using small pieces of charcoal, the heat may be moderated so as to be employed with flasks and retorts, as well as crucibles.
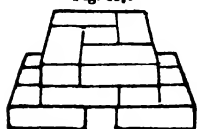
Fig. 137.

487. In all cases where a strong heat is required, all apertures leading into the chimney above the place where the fuel rests ought to be closed, and any of the apertures leading into the chimney from any furnace not in use must also be shut; otherwise, cold air rushing in by them reduces the temperature of the warm ascending current, and consequently reduces also the temperature in those furnaces in use, by preventing so rapid a consumption of the fuel.

488. Where many furnaces play into one chimney, if it be not sufficiently large and powerful, only part of them ought to be used at the same time, the apertures that connect the rest with it being closed.

489. If the smoke from a common fire be not carried up the chimney, and if there be sufficient air allowed to enter by the doors or windows, then, by closing the aperture between the top of the fire and the chimney, so that no air can have access to it except through the fuel, the smoke may in general be prevented from returning.

490. All furnaces where a steady and regulated temperature is required, must be provided with ash-pit doors, by which a fixed and steady supply of air can be admitted, and regulated so as to produce a powerful or moderate heat. By cutting off altogether the supply of air, the fuel may be kept unconsumed for any length of time.

SECT. III.—HYDRURET OF CARBON, OR OLEFIANT GAS.

Symb. HC. *Eq. by W.* 7.12 *(Carbon* 6.12 + 1 *Hydrogen), by volume,* □ *(half a measure). Sp. gr.* .982 ; *W. of* 100 *c. i.* 30.44 *gr.**

491. This gas is most easily prepared by mixing one part of alcohol with three times its bulk of strong sulphuric acid in a glass-retort, and exposing the mixture to a gentle heat. The retort should not be filled more than a third full, and when only a small quantity of the gas is required, half an ounce of alcohol with the proper quantity of sulphuric acid will be found quite sufficient. The alcohol and the acid must be shaken together before the heat is applied. A little ether is formed at first, and towards the end of the process, sulphurous acid, carbonic oxide, and the bihydruret of carbon (another compound of carbon and hydrogen) are disengaged; the mixture also becomes quite black from the deposition of carbon, and is very apt to boil over.

492. To understand the nature of the changes that take place in this process, it must be recollected that every 23.24 parts, or one eq. of alcohol, is composed of 3 parts of hydrogen (three eqs.), 12.24 of carbon (two eqs.), and 8 of oxygen (one eq.) ; so that it may be regarded as a compound of one equivalent of water and two of olefiant gas, for the different elements are present exactly in the proportions necessary to form these compounds. The water then may be said to combine with the sulphuric acid, while the olefiant gas is disengaged ; the new arrangement which the elements of the alcohol assume is represented in the following diagram.

Fig. 138.

Before Decomposition.		After Decomposition.
	Hyd. 1	7.12 Olefiant Gas.
	Hyd. 1	7.12 Olefiant Gas.
Alcohol 23.24	Hyd. 1	
	Carb. 6.12	
	Carb. 6.12	
	Oxyg. 8	9 Water.

Symb. OC² H³ = 2 HC & ·H.
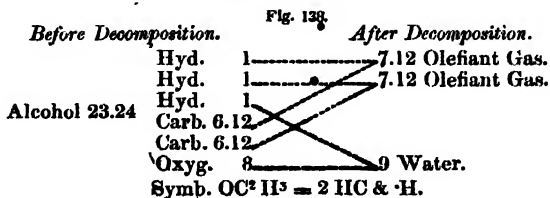
* The equivalent of this gas is doubled in many works, being thus regarded as a compound of two eqs. of hydrogen and two of carbon.

493. At the commencement of the process, a portion of olefiant gas uniting with some alcohol not decomposed, forms a little ether, the odour of which is then always perceptible. The black colour which the liquid assumes afterwards, and the formation of bihydruret of carbon, arise from the elements of the alcohol not previously decomposed, arranging themselves in a different manner, which will be readily understood from the annexed diagram :—

Fig. 139.

Before Decomposition.   *After Decomposition.*

Alcohol 23.24

Hyd.   1 _____ 8.12 Bihydruret of Carbon.
Hyd.   1
Hyd.   1
Carb. 6.12
Carb. 6.12 ____ 6.12 Carbon precipitated.
Oxyg.   8 _____ Water.

Symb $OC^2 H^3 = H^2 C \& C \& \cdot H \cdot$
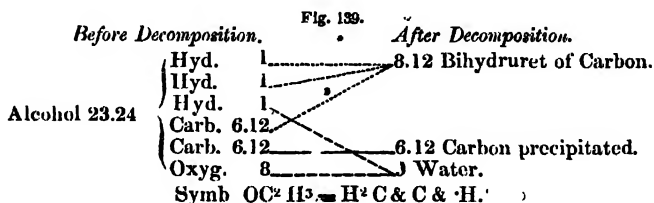
But no sooner is the carbon precipitated than it begins to re-act upon the sulphuric acid, taking one equivalent of oxygen from it and being converted into carbonic oxide, while the sulphuric acid becomes sulphurous acid in consequence of losing this proportion of oxygen. A small quantity of carbonic acid is also formed towards the end of the process. The proportion of these gases that is disengaged in the succeeding stages of the process becomes greater and greater as it proceeds ; the sulphurous and carbonic acids may be removed by a solution of caustic potassa.

494. A large quantity of this gas, mixed with other inflammable compounds of carbon and hydrogen, may be procured by exposing oil and resinous or fatty substances to a red heat in close vessels. It is in this manner that oil-gas is prepared on the large scale, which owes its great illuminating power principally to the olefiant gas which it contains. The process may be imitated on the small scale in the apparatus described in 58, page 20, using oil instead of water, and putting in iron shavings or fragments of earthen ware, merely to extend the surface. The tube must be brought to a good red heat before the oil is allowed to drop into it. All these inflammable substances are composed almost entirely of carbon and hydrogen, and by exposure to a high temperature their elements arrange themselves so as to

form a large quantity of gaseous matter, while a considerable portion of carbon is deposited.

495. An inflammable gas may be obtained from alcohol in the same way, but it does not burn with such a rich flame, and contains carbonic oxide and bihydruret of carbon along with olefiant gas.   Instead of having the apparatus constructed in the manner represented in 58, it is sometimes more convenient to have it made of cast iron in the form shewn in figure 33, page 20.   Its construction and the manner of using it will be readily understood from the figure and what has been stated in 58–9.   It may be heated by placing it in a large chauffer with a piece cut out at the side, or in a furnace.

496. An inflammable gas from coal, containing a considerable quantity of olefiant gas, may be easily obtained in small quantity by heating some pieces of coal in an iron bottle placed in the fire, a quantity of tar, water, and carbonate of ammonia being at the same time distilled over.   The process is an offensive one, and in town it will be better to procure a quantity for experiment by attaching an empty bladder, or the stopcock b of the gasometer represented in Fig. 15, page 9, to the extremity of a tube supplying gas to a burner from the coal gas-works, by corks with holes pierced in them and flexible tubes.   The plug at c is taken out that the water may escape as the gas enters, and great care taken not to allow any air to mix with it.   A piece of sponge put into the plug-hole prevents the water from coming out too rapidly; the stopcock that admits the gas to the gasometer should be opened wide, but not till the sponge has been put in.   The gas that is disengaged from coal by heat does not consist solely of compounds of carbon and hydrogen, but contains also carbonic oxide, carbonic acid, nitrogen and hydrosulphuric acid; the proportion of these is small, though sufficient to render the gas less luminous during its combustion, and impart other sensible properties to it.   The ammonia is produced by the combination of part of the nitrogen and hydrogen of the coal when it is decomposed; and part of the carbonic acid unites with it, and converts it into the carbonate of ammonia.   The gas prepared from coal at the different gas establishments is purified by being passed through lime and water.

497. Olefiant gas burns with a rich yellowish-white flame when inflamed in contact with the air, and consumes a large

quantity of oxygen, requiring three times its bulk of this gas for its complete combustion. With pure oxygen it detonates violently when the gases are mixed in the above proportion; an excess of oxygen insures the perfect combustion of all the olefiant gas used, but no oxygen is consumed above the proportion mentioned ; a strong detonating bottle must be used in performing this experiment, and it should be wrapped round with a towel, in case of accident. The products of its combustion are water and carbonic acid. In the following diagram the theory of the action is represented, and the quantities of the resulting products :—

* Fig. 140.

Before Decomposition.   *After Decomposition.*

```
7.12 Olefiant Gas = { Carb. 6.12,  ------------22.12 Carbonic Acid.
                     { Hyd. . . 1.
                     { Oxyg. . 8.
     24 Oxygen    = { Oxyg. . 8.
                     { Oxyg. . 8------------9 Water
              HC & O³ = ·H & :C.
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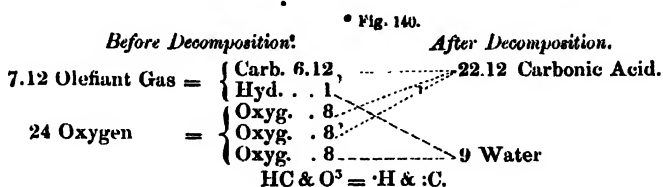
As the watery vapour is immediately condensed at natural temperatures, one measure of carbonic acid is the only gaseous product that results from the detonation of the half measure of olefiant gas.

498. Water absorbs about an eighth of its volume of olefiant gas, but does not acquire any particular properties. By passing electric sparks through this gas, or transmitting it through a red-hot porcelain tube (202) it is decomposed, the hydrogen resuming its original volume, while the charcoal is deposited. It can combine with chlorine, iodine, and bromine. Some other experiments, which may be performed easily with olefiant gas, will be described under chlorine.

SECT. IV.—BIHYDRURET OF CARBON, OR LIGHT CARBURETED HYDROGEN.

Symb. H^2C. *Eq. by W.* 8.12 *(Carbon* 6.12 + 2 *Hydrogen); by volume* □. *Specific gravity* 0.559. *Weight of* 100 *cubic inches* 17.363 *grains.*

499. This gas is also known by the name of *Fire Damp* (being the inflammable air that produces the explosions that occur

in-coal mines), *Subcarbureted Hydrogen*, and a variety of other appellations. It is procured most easily by stirring the mud at the bottom of stagnant pools, and collecting the gas which is disengaged in glass vessels inverted over it and full of water, a large quantity being formed there by the decomposition of dead vegetable matter. No process has been pointed out by which it may be obtained with facility in a pure state. It is almost always mixed with a small quantity of carbonic acid when obtained in the manner we have described, and also when procured from a coal-mine ; by agitating it with lime-water or a solution of potassa, the acid gas is removed.

Small quantities are formed in a great number of processes, as in some of those for the preparation of olefiant gas, and most vegetable substances afford a considerable quantity when they are exposed to heat in close vessels

500. The bihydruret of carbon has neither taste nor smell when pure, cannot support combustion or respiration, and is absorbed very sparingly by water. It burns with a yellow flame, and consumes twice its volume of oxygen during its combustion, the two equivalents of hydrogen which it contains in a condensed state combining with two equivalents of oxygen and forming two of water, while the carbon unites with as much more, and is converted into carbonic acid. When mixed in the proper proportion with oxygen in a strong bottle and fired with a match, it detonates with a loud explosion. It also detonates with atmospheric air.

501. Purified coal-gas may be obtained in the manner directed in 496 from a gas-burner supplied by the gas-works, for performing several experiments illustrating the nature of Sir H. Davy's safety-lamp, as a sufficient quantity of the pure bihydruret of carbon cannot be so easily procured. The coal-gas consists principally of olefiant gas and the bihydruret of carbon.

. 502. Mix the gas with various proportions of atmospheric air in a strong jar or detonating bottle. The pure bihydruret does not detonate unless mixed with more than four times its volume of atmospheric air, and the explosion is feeble till seven or eight times its bulk is added. With more than fourteen times its volume of air it does not form an explosive mixture, a candle merely burning in it with an enlarged flame. The proportion of air necessary for performing the same experiments with the

coal-gas will require to be greater, as, from the olefiant gas which it contains, more oxygen is required for its combustion.

503. Mix it in the same manner with different proportions of pure oxygen; the detonation takes place violently with two or three times its bulk of this gas. The products of the combustion are water and carbonic acid. A very strong jar or detonating bottle must be used, and three or four cubic inches of gas will be quite sufficient for each experiment when oxygen is used.

504. Introduce the safety-lamp when burning into mixtures of air and coal-gas in various proportions; the mixture passes through the meshes of the wire-gauze and burns within it, the flame extending and striking against the top of the gauze, when it is again reflected downwards, but never inflaming the inflammable mixture without the cage.

505. Connect a flexible tube with the gasometer,

and direct a large stream of the gas upon the lamp held in the open air, after it has been lighted and properly adjusted. By varying the distance at which the lamp is held from the gas, it will either burn with a larger flame, or be completely extinguished, when the quantity of gas which falls upon it is so great as to prevent the admission of atmospheric air; the inflammable atmosphere around, however, is never inflamed.

506. The construction of the safety-lamp is represented in the annexed figure (141). A wire recurved at the top passes through the cistern containing the oil and without the lamp; it is called the safety-trimmer, as with it the wick of the lamp may be trimmed without taking off the gauze. The wire-gauze is fixed to a brass rim, which is made to screw upon the cistern containing the oil. It admits the air to support the combustion through its apertures, and has a double top, one being placed at some distance from the other as an additional security.

507. The cause why the safety-lamp does not inflame an inflammable mixture without the gauze, though it can enter freely and burn within, has
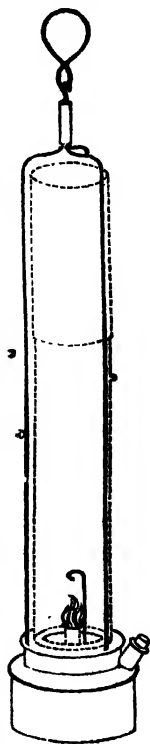
been satisfactorily explained. A very great heat is required to inflame most bodies in the gaseous state, and when they become luminous so as to constitute flame, their temperature is above the white heat of solid bodies. But when any gaseous matter in the state of flame passes through the minute apertures of the wire-gauze, its temperature is so much reduced that it ceases to be luminous, and is incapable of inflaming any explosive mixture that may be without. The metal of which it is composed, being a good conductor of caloric, gives it off quickly to the external air when heated, so that it is always sufficiently cool to reduce the temperature of any gas that may be burning within the gauze as it passes through; nor does it ever become so hot as to be able to inflame an explosive mixture itself, unless it be kept for some time in it, or exposed to it when the explosive mixture passes across it in a rapid current. In such cases the lamp ought to be extinguished. It has been proposed, as an additional security, to cover it with a glass, the air being supplied from an aperture below protected by wire-gauze.

Coal and oil gases consisting principally of the hydruret and bihydruret of carbon, the following illustrations (from my Rudiments of Chemistry) should be carefully studied by the beginner.

508. Bihydruret of carbon acts with four equivalents of air, producing one of carbonic acid and two of water, eight of nitrogen being detached. Symb. $H^2C \& 4 \cdot N^2 = :C \& 2 \cdot H$ and 8N.

509. The flame of a common lamp or candle is produced by the gas formed around the wick acting upon the oxygen of the air ; the flame is solely at the exterior portion of the ascending gas. In Fig. 142, aa denotes the part in a state of combustion. All without is merely heated air, or the products of the combustion ; and all within is unconsumed gas, rising in its turn to affect the oxygen of the air.

Fig. 142.

510. If a glass-tube be introduced within the flame of a large lamp or candle, in the manner represented in Fig. 143, part of the unconsumed gas passes through it, and may be kindled as it escapes. With a tube 1–4th of an inch in diameter, and a foot long, this is very easily shewn ; the wider the tube the better, if the flame be sufficiently large.

Fig. 144 shews a section across the flame, with the position of the tube.

Fig. 143.

Fig. 144.
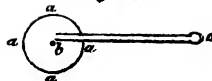
Fig. 145.
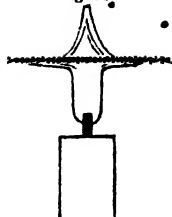
511. The nature of flame is beautifully illustrated by holding over the flame of a candle, or of a large stream of gas, a piece of wire-gauze six or eight inches square, with about 700 meshes in the square inch. The flame is intercepted, and continues only below the gauze, a tube of flame appearing, expanded as it reaches the gauze. The unconsumed gas rises through the gauze, and if a lighted match be applied, it burns on the upper side; the appearance is then presented as seen in Fig. 145. When this experiment is performed with coal-gas issuing from the extremity of a tube, and producing a flame, which does better for illustration if made considerably larger than the flame of a common candle, the flame may be blown out below the gauze, and left in full combustion above it. On kindling the gas again below the gauze, the flame may then be blown out above it, without extinguishing that below.

512. The intensity of light produced during the combustion of any gaseous matter, depends much upon the manner in which the gas is consumed. To produce a highly luminous flame, attention should be paid to the following circumstances:—

    I. The combustion must be made to take place in such a manner, that an intense heat is produced.

    II. The gas, as yet unconsumed, is decomposed by the heat, and much solid charcoal is separated and suspended in the flame for an instant.

    III. This charcoal must be intensely heated, so as to be consumed. Any unconsumed charcoal gives a yellowish tinge to the flame, and, if in large quantity, is deposited ultimately in the form of soot.

    IV. The less the heat produced in burning gas, the less the charcoal separated, and the more imperfect its combustion.

513. In an argand burner, Fig. 146, the intensity of the heat is augmented by causing air to enter in the middle of a circular wick of series of gas jets, so that more gas is consumed within a given space than in the ordinary manner. Thus in Fig. 147, a section of the argand burner, Fig. 146, it will be seen that the surfaces of the burning gas *aa*, *aa*, are very near, so that the interposed gas is heated much more than when these surfaces *aa* are distant, Figs. 142 and 148. Much carbon therefore is precipitated, and becomes intensely luminous before it is consumed.
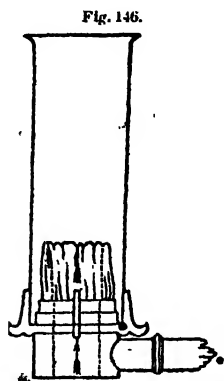
Fig. 148.
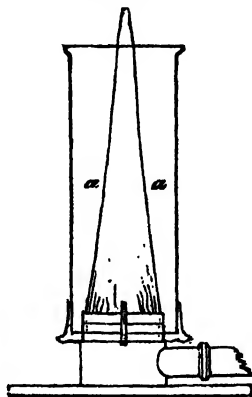
Fig. 146.

Fig. 147.

514. If the aperture by which air is admitted into the interior of the flame be closed by a piece of paper, the flame represented in Fig. 146 immediately assumes the form shewn in Fig. 148; part of the supply of air being cut off, it extends farther into the air before it meets with the oxygen necessary for combustion. The heat is accordingly diffused over a larger surface, and becomes less intense ; *a* and *a* are more distant from each other; a smaller quantity of carbon is deposited, less gas being decomposed, and even that which is separated being less intensely heated, much of it is unconsumed, and produces a dingy and imperfect flame.
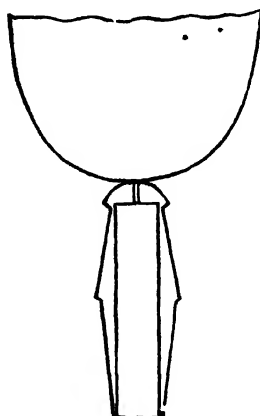
Fig. 149.   Fig. 150.

515. The most perfect form of burner is seen in the flat gas
jet, Fig. 149, where two opposing currents of gas meeting each
other, flash into an extremely thin sheet of gas, which extends
in an opposite direction to the currents which produce it. Fig.
150 is a section of the same jet, the side of the flame being
turned towards the eye. Here, the gas on one side being so
extremely near that on the other, all the conditions are fulfilled
which are necessary for intense heat and light.

Fig. 151.

.516. For some purposes where gas is used, it escapes
with too much force to be employed conveniently.; as in
experiments with the blowpipe. By placing over it a
a small brass tube, Fig. 151, covered with wire-gauze, a
better flame for this purpose is procured.

517. If air be mixed with gas before it is inflamed, as by al-
Fig. 152. lowing it to rise in a tin chimney, to which the air has
free access on every side, wire-gauze being placed over
the top of the chimney, a flame is produced which is not
more luminous than that of a spirit of wine lamp, and
produces no smoke. Fig. 152 illustrates the arrangement
adopted. It is easy in this way to procure a flame from
an inch to a foot in diameter. Burners of this kind have
been much used of late for the steady application of heat,
both for domestic purposes and in the laboratory of the chemist.

SECT. V.—BISULPHURET OF CARBON.

Symb. S²C.   *Eq.* 38.32 *(Sulphur* 32.2 + 6.12 *Carbon)*; *Sp. gr.*
1.272.   *It boils at* 110°.

518. To prepare this substance, a porcelain tube (an inch or
more in diameter) is coated with clay and wrapped round with
iron wire. It is then filled with fragments of charcoal, taking
care to leave room for the passage of vapour, and made to tra-
verse a furnace in the manner represented in figure 153. A
retort filled about a third full of sulphur is then fitted to one
end of the tube, supporting it by a retort-stand, and using a
mixture of clay and sand to make the joining air-tight. A
bent glass-tube about half an inch or rather less in diameter is
attached in the same manner to the other extremity of the

porcelain tube, and con-
nected with a glass
globe terminating in a
small tube placed in a
receiver half full of
water, which must be
kept cold.

519. When every
thing has been properly
adjusted, fire is put into
the furnace, and the
tube with the charcoal
brought gradually to a

Fig. 153.

strong red heat. The sulphur in the retort is then made
to pass over it in vapour; they combine, and the bisulphuret
which is formed condenses in drops that fall to the bottom of
the water in the receiver. The use of the globe is to prevent
any water passing back to the porcelain tube, air passing through
the water, after it has been forced into the globe by the pressure
of the atmosphere when the chauffer is removed from the re-
tort. The charcoal employed should be well prepared, and not
mixed with any undecomposed woody fibre.

520. Another process consists in distilling it from a mixture
of five parts of the bisulphuret of iron and one of charcoal, a
strong heat being applied to the mixture.

521. The bisulphuret of carbon is never obtained perfectly
pure at first, but may be easily rectified by a second distillation,
putting in a little chloride of calcium to retain any water that
may be mixed with it. The temperature to which it is exposed
must not exceed 110°. It is then procured in the form of a
limpid and colourless liquid, remarkably transparent, having a
very offensive and fetid smell, and an acrid pungent taste.

522. Bisulphuret of carbon is very volatile, evaporating rapidly
at natural temperatures, and producing a great degree of cold.
It is highly inflammable, and burns with a bluish flame. With
oxygen gas, its vapour detonates violently, and with oxide of ni-
trogen it burns very rapidly, but does not detonate, producing a
very brilliant and dazzling light. These experiments are made
most easily by filling a detonating bottle full of oxygen gas or oxide
of nitrogen gas, putting in a few drops of the bisulphuret, and
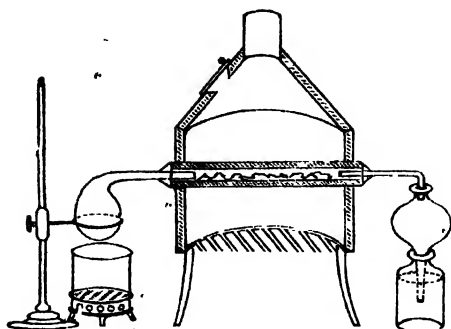
shaking the bottle (after corking it tightly) till the bisulphuret is volatilized ; the mixture is then-inflamed in the usual manner.

523. Alcohol and ether combine with this substance, and it dissolves sulphur, phosphorus, and iodine ; chlorine, however, decomposes it   It combines with the alkalis, forming compounds which have been termed carbo-sulphurets ; and when agitated with an alcoholic solution of potassa, a new acid is produced, called the Hydroxanthic Acid, from Xanthogen (derived from ξανθος, *yellow*), the name given to its base, as it forms yellow coloured compounds with several metals.

CHAP. VIII.—BORON.

Symb. B.   *Eq. by W.* 11 ! .

524. Sir H. Davy, who discovered Boron, prepared it by submitting boracic acid, a compound of boron and oxygen, to the action of a galvanic battery. Gay Lussac and Thenard procured it in greater quantity by exposing boracic acid to a red heat in a copper tube with its own weight of potassium, the latter attracting oxygen from it and forming potassa, which is easily removed by washing with water ; the boron remains in the solid form and of a dark olive colour.   The boracic acid ought previously to be deprived of water as completely as possible by protracted fusion in a platinum crucible, but as it still retains some, a detonation takes place at the instant of reduction, from the potassium reacting at the same time on the water combined with the acid and disengaging hydrogen gas.   To avoid this, Berzelius recommends the dry borofluate of potassa to be used instead of boracic acid ; it is prepared by adding a solution of the hydrofluate of potassa to a solution of borate of potassa, and heating the gelatinous precipitate that is thrown down till it assumes the form of a fine white powder.   The theory of the action is the same as in the preceding process, the potassium taking the oxygen from the boracic acid in the compound salt.

525. Boron has no taste nor smell, is insoluble in water and in alcohol, and undergoes no change when exposed to the air at ordinary temperatures, but inflames suddenly when heated to 600°, being converted into boracic acid by combining with the

oxygen of the air. In oxygen gas it burns more brilliantly, and attracts oxygen from a number of substances that afford this element readily, as the sulphuric and nitric acids, the nitrate and chlorate of potassa.

Boracic Acid.

Symb. O³B, *or* ⋮ B ; *Eq.* 35 *(Oxygen* 24 + 11 *Boron)*. *Eq. of crystallized boracic acid,* 62 *(dry acid* 35 + 27 *water) ; specific gravity,* 1.479. *It is soluble in water and in alcohol.*

526. To prepare boracic acid, dissolve an ounce or two of crystallized borax (a compound of water, boracic acid, and soda) in four times its weight of boiling water, add sulphuric acid previously diluted with four or five parts of water till the solution becomes sensibly acid (using a test paper to ascertain when this is the case), and then set it aside to crystallize. The sulphuric acid combines with the soda, forming sulphate of soda which remains in solution, and crystals of boracic acid are deposited which are purified by placing them on a paper filter, and washing them with cold water to remove any sulphate of soda that may be mixed with them. A minute portion of sulphuric acid is apt to adhere to them still, which can be removed only by repeated solution and crystallization, or by fusion in a platinum crucible ; in all ordinary experiments its presence is of no consequence.

527. Boracic acid crystallizes in thin scales which have a shining appearance. Its taste is sour and bitter ; it reddens the vegetable blues, but produces the same effect on turmeric paper as the alkalis, rendering it brown, as Dr Faraday pointed out. Crystallized boracic acid loses its water of crystallization when exposed to a heat slowly increased, and the dry acid which remains is fused and forms a transparent and colourless glass on cooling. When a solution of boracic acid in water is boiled, or the crystallized boracic acid exposed suddenly to a high temperature, a considerable portion of it is carried along with the vapour of the water ; but the dry acid may be exposed to a white heat without being volatilized. From the facility with which it

is fused, and the power which it has of communicating this property to its compounds, it is much employed, both in its pure state and in combination with soda, as a flux.

CHAP. IX.—CHLORINE.

Symb. Cl. *Eq. by W.* 35.5; *by volume* □. *Specific gravity* 2.444. *Weight of* 100 *cubic inches* 75.8 *grains. It is liquefied by a pressure of about four atmospheres, and also by the cold produced by the evaporation of sulphurous acid, forming a transparent yellow-coloured fluid.* 100 *c. i. of water absorb* 150 *c. i.*

528. This elementary substance was discovered by Scheele, and received afterwards the name of Oxygenized Muriatic acid or Oxymuriatic acid, from the opinion which was then prevalent that it is a compound of muriatic acid and oxygen. Till the researches of Sir H. Davy drew the attention of the philosophical world to this subject, it was indeed considered as demonstrated that this is the case ; Gay Lussac and Thenard pointed out about the same time that it may be regarded either as a simple substance or as a compound of muriatic acid and oxygen ; and though the views of Sir H Davy, who has certainly the merit of placing the question on a proper footing, have now been generally adopted, it is not a little singular that there is no fact connected with the chemical history of this substance which is not explicable according to either opinion, and in some cases the balance of evidence appears even to be in favour of the old view of its constitution.

529. The best method of preparing chlorine consists in mixing one part of the binoxide of manganese with five times its weight of aqueous hydrochloric acid (specific gravity·1.18) in a glass retort, collecting the gas in wide-mouthed bottles placed on the shelf of the pneumatic trough, and conducting the process with all the precautions described in 4 and 14. If the aqueous hydrochloric acid employed should not be of this specific gravity, its strength must be ascertained, and a corresponding quantity used. The manganese should be reduced previously to a fine powder, and the water in the trough and in the bottles heated to the temperature of 90°, to prevent it from absorbing a large

quantity of the chlorine. The retort should not be filled more than half full; the gas begins to be evolved whenever the materials are mixed, and, on applying a gentle heat by a lamp or chauffer, it is disengaged more rapidly. Each bottle should have its stopple introduced under water whenever it is full, first drawing the finger round the edge with a little gas lute, that it may be easily taken out afterwards. Common pneumatic jars may be employed to collect the gas when it is to be used immediately, but it must be recollected that it will be all absorbed if it be left for a long time over water.

530. In this process, one equivalent of chlorine is obtained from two of hydrochloric acid and one of binoxide of manganese, the materials reacting on one another in these proportions. Hydrochloric acid is composed of one equivalent of hydrogen and one of chlorine, and the binoxide of manganese may be regarded as a compound of one equivalent of the oxide of manganese and one of oxygen. During the reaction which takes place, the oxide of manganese combines with one equivalent of hydrochloric acid, forming hydrochlorate of manganese, the excess of oxygen at the same time combining with the hydrogen of the other equivalent of hydrochloric acid, while the chlorine is disengaged; the annexed diagram gives a more precise view of the combinations and decompositions which take place.

Fig. 154.

Before decomposition.   Products.

36.5 Hydrochloric Acid { Chlorine... .. 35.5   35.5   Chlorine
                         { Hydrogen ...   1----- ------> 9   Water
36.5 Hydrochloric Acid ....•.......•... 36.5
43.7 Binox. Mang.   { Oxygen 8
                         { Oxide Mang.   35.7-------- 72.2 { Hydrochlo.
                                                              of Mang.

Symb. 2 HCl & :Mn ÷ Cl & ·H & HCl ·Mn.
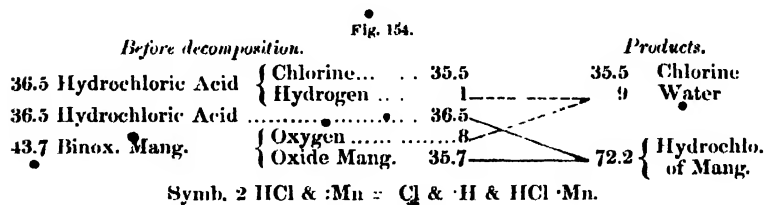
531. As the common aqueous hydrochloric acid contains more than half its weight of water, even in its most concentrated state, and as part of it escapes decomposition, it is necessary to make allowance for these circumstances, and hence the large quantity which is directed to be mixed with the manganese in the preceding paragraph. 500 grains of the binoxide of manganese with the proper quantity of acid will give a sufficient quantity of chlorine for the greater number of the experiments usually performed with this substance, receiving it in wide-

mouthed bottles capable of containing from 6 to 10 or 12 ounces of water.

532. Another process for preparing chlorine consists in mixing 43.7 parts of the binoxide of manganese intimately with 59 of chloride of sodium (dried common salt, a compound of chlorine and sodium) in a mortar, and pouring on the mixture 98.2 parts of sulphuric acid previously diluted with half its weight of water and allowed to cool. Three or four hundred grains of salt will be a sufficient quantity on the small scale, using a proportional quantity of the other materials, and placing them in a retort or flask with a bent tube adapted to it; the apparatus used for the preparation of hydrogen gas (Fig. 26, page 17), does very well when a larger quantity is employed, supporting it on a retort-stand that heat may be easily applied. The sulphuric acid is diluted to prevent the copious disengagement of hydrochloric acid fumes which always takes place when strong sulphuric acid is poured upon chloride of sodium. All the other circumstances pointed out in 529 must be carefully attended to.

533. It will be observed, that the materials are directed to be taken in the proportion of two equivalents of sulphuric acid to one of the binoxide of manganese and one of the chloride of sodium. One equivalent of the acid, reacting on the binoxide of manganese, forms sulphate of the oxide, and disengages one equivalent of oxygen, (see 27, page 11); this combines with the sodium of the chloride, forming soda, which immediately unites with the other equivalent of sulphuric acid, producing sulphate of soda, while the chlorine is disengaged. In the following diagram representing the decomposition, the quantity of sulphuric acid is stated without the water that is usually combined with it, as it is not decomposed in the present instance.

Fig. 155.

Before decomposition.		After decomposition.
59 Chloride of Sodium.	Chlorine 35.5	35.5 Chlorine.
	Sodium......... 23.5	
43.7 Binox. Mang.	Oxygen......... 8	
	Oxide Mang. 35.7	
40.1 Sulphuric Acid	40.1	71.6 Sulph. of Soda.
40.1 Sulphuric Acid	40.1	75.8 Sulph. of Mang.

534. The evolution of the chlorine may be explained also on the supposition that sulphate of soda is formed at first, as well

as sulphate of manganese, the chloride of sodium decomposing an equivalent of water, and becoming hydrochlorate of soda, from which the hydrochloric acid escapes as the sulphuric acid combines with the soda ; while the oxygen disengaged from the manganese withdraws hydrogen from the hydrochloric acid at the same moment, and eliminates the chlorine.

535. Chlorine gas has a greenish-yellow colour, a pungent suffocating odour, even when diluted with a large quantity of air, and a disagreeable astringent metallic taste. In operating with it, care must be taken not to allow any to mix with the air, as it has often produced a degree of irritation in the lungs and an anxiety and difficulty of breathing with a total inability of taking a full inspiration, which have lasted for days, even when a single inspiration has been made, and though mixed with several times its bulk of air. In larger quantities, it produces a sense of strangulation with a discharge from the nostrils ; and in manufactories where considerable quantities are prepared, some of the workmen have occasionally fallen down quite senseless in an instant, when they have been exposed accidentally to a current of the gas. In these cases they are removed immediately to the open air, and generally recover very quickly on dashing cold water upon them. It appears, too, that some of those who have been affected in this manner never experienced any of the bad effects that accompany the inspiration of the gas when diluted with air, probably from the great irritation it occasions in a pure state causing a complete spasm of the glottis, and preventing any of it from passing into the lungs ; the individual, therefore, suffers from the temporary suspension of respiration alone. Where the gas has passed into the lungs, it has been recommended to take a drink composed of the water of ammonia diluted with a very large quantity of water, to respire a little ammoniacal gas by keeping the mouth over some ammonia diluted with a less quantity of water, and to inhale the vapour of ether ; if nothing else can be procured at the moment, considerable relief may be obtained by holding the head over a large jar half full of hot water, and breathing into it.

536. Water absorbs one and a half times its volume of chlorine gas at the temperature of 68°, according to Thenard. The solution is called in common language Liquid or Aqueous Chlorine, or Chlorine Water. It has the colour, taste, and smell of

chlorine ; it is stimulant and antiseptic ; and gives chlorine gas when exposed to heat. This solution is most easily prepared in the manner directed for obtaining carbonic acid water, in 446 ; or the gas may be transmitted through water placed in the third bottle of Woulfe's apparatus (Fig. 101, page 90), a small quantity of water being placed in the first and second to retain any hydrochloric acid that may be disengaged along with it.

537. Expose a portion of this liquid to the temperature of 32° by placing it in ice-cold water, or surrounding it with a freezing mixture ; it soon begins to congeal, and affords a solid mass of a yellow colour, composed of chlorine and water. Crystals of a definite compound of these substances are easily obtained free from any excess of water by dropping a small quantity of water into a bottle filled with chlorine gas, and placing it in a freezing mixture, or in the dark at a temperature below 32° for a few days. They form dendritical crystals on the side of the bottle.

538. Aqueous chlorine has no acid properties, but when exposed to the light, part of the water is slowly decomposed, one portion of the chlorine combining with the hydrogen and forming hydrochloric acid, while the other combines with the oxygen ; it ought therefore to be kept in opaque bottles. From the great attraction that subsists between chlorine and hydrogen, aqueous chlorine communicates oxygen to a number of metals and other substances which have an affinity for this element, the chlorine uniting with the hydrogen of a portion of water which is decomposed, and liberating oxygen.

539. Chlorine is particularly distinguished by its power of destroying all vegetable and animal colouring matters, and decomposing effluvia produced by contagious diseases, or arising from vegetable or animal matter in a state of putrefaction. It is accordingly employed extensively for bleaching and fumigation, and is used for these purposes either in the gaseous state, or in combination with lime or an alkali and dissolved in water. Aqueous chlorine is also frequently employed on the small scale, and a number of experiments may be made with the liquid directed to be prepared in 536, by pouring it into solutions of vegetable colouring matter, as litmus, turmeric, indigo, and into others in a state of putrefaction, when their colour or odour will be completely destroyed, if it be added in

sufficient quantity. The method of making chloride of lime and Labarraque's disinfecting soda liquor will be described under their respective bases.

540. Suspend some coloured flowers in a bottle of chlorine gas, after putting in a few drops of water : in a short time in general they will become of a pure white colour; but some are much more speedily deprived of colour than others.

541. When chlorine gas is perfectly dry, vegetable colouring matter is not at all affected by it, and from a variety of experiments made with substances of this nature, it appears that chlorine acts principally by decomposing water, combining with its hydrogen and forming hydrochloric acid, while the oxygen that is eliminated acts directly on the colouring matter and destroys it.

542. A number of inflammable substances burn in chlorine gas, and many of them take fire when mixed with it at natural temperatures.

543. Light a suspended candle (Fig. 9, page 5), and put it into a bottle of chlorine gas. It continues to burn, but with a dull red flame, and a large quantity of carbon is deposited. The combustion is sustained by the chlorine combining with the hydrogen of the inflammable matter, while the carbon is precipitated. If a candle with a red-hot wick be introduced into chlorine gas, it is rekindled so as to burn with flame.

544. Pour some oil of turpentine on the lower part of a piece of thin grey paper folded in the form of a match, allow any excess to drop off, and then put it into a bottle of chlorine, holding it with a pair of pincers. The oil of turpentine will immediately take fire and burn with a lurid flame, the same reaction taking place as in the preceding instance, and with a similar deposition of carbon.

545. Mix half a measure, or one equivalent, of olefiant gas (a few cubic inches of the gas or a much larger quantity may be employed) with a whole measure or one equivalent of chlorine in a glass jar, and apply a light to the mixture ; it will burn quickly with a flame similar to what is produced by the combustion of oil of turpentine in chlorine, the hydrogen combining with the chlorine and forming hydrochloric acid while the carbon is precipitated. (See Hydrocarburet of chlorine.)

546. Introduce a piece of phosphorus well dried (363) into

another bottle of chlorine, using the copper-cup represented by Fig. 73, (page 50). It immediately takes fire and continues to burn for a considerable time with a pale flame, combining with the chlorine, and forming bichloride of phosphorus ; a grain or two will be quite sufficient for a small bottle of the gas.

547. All the metals can combine with chlorine ; many of them take fire in this gas at natural temperatures, when introduced into it in a minute state of division. When exposed to heat, the greater number of the other metals act in a similar manner with chlorine, with the exception of gold, silver, lead, cobalt, and nickel.

548. To see the phenomena attending the combination, put some leaves of Dutch gold, a compound of copper and zinc, into the cage represented in Fig. 74, page 50, and introduce them into a bottle filled with chlorine ; they immediately inflame, and chlorides of copper and zinc are formed.

549. Throw some antimony or arsenic, reduced to powder in a mortar, into another bottle of chlorine ; the metal immediately inflames and combines with the chlorine.

550. Put some mercury into an iron cup, Fig. 73, page 50, rubbed over with a little gas lute to prevent the metals from combining, heat it in the flame of a spirit-lamp, and place it in a bottle of chlorine. It takes fire, burning with a reddish-coloured flame, and is converted into bichloride of mercury.

551 Chlorine can decompose many of the metallic oxides (including the alkalis and earths) at a high temperature; an equivalent of oxygen is disengaged for every equivalent of the oxide that is decomposed, one equivalent of a metallic chloride being at the same time formed. The metallic oxide to be decomposed is placed in a coated porcelain tube, which is made to traverse a furnace in the usual manner (Fig. 31, page 20). The chlorine is prepared in a flask or retort ; it is better to employ a tubulated retort. It is first passed over fragments of fused chloride of calcium placed in a small globe or tube attached to its beak, and luted with plaster of Paris to the porcelain tube ; in this manner it is freed from water before it comes in contact with the oxide. The oxygen evolved is collected in a jar over the pneumatic trough, to which it is conducted by a bent glass-tube

fixed to the other extremity of the porcelain tube. The current of chlorine should be passed slowly but steadily over the oxide.

552. Chlorine is detected by a solution of the nitrate of silver, which gives a dense white curdy precipitate with it, composed of chlorine and metallic silver ; this precipitate is soluble in ammonia, but insoluble in acids, and becomes of a dark colour on exposure to the light.

Sect. I.—Hypochlorous Acid.

Symb. ·Cl.   *Eq. by W.* 43.5 = *Chlorine* 35.5 + *Oxygen* 8.   *Eq. by volume* □ *(chlorine* □ + □ *oxygen).   Gaseous when combined, but condensed in large quantity by water, which absorbs upwards of* 100 *times its bulk of this gas.*

553. This compound is usually prepared by the action of chlorine on solutions of potassa or soda, or on the hydrate of lime. One eq. of chlorine unites with the metallic base of the alkali or earth, forming a chloride, while the other combines with its oxygen and produces hypochlorous acid, which remains in combination with another eq. of the alkali or earth employed.

554. To obtain the hypochlorous acid in solution, binoxide of mercury in fine powder is mixed with twice its weight of distilled water, and agitated in a bottle containing chlorine, till the gas is absorbed. Part of the chlorine combines with the oxygen, forming hypochlorous acid, which remains in solution. The remainder of the chlorine combines with metallic mercury, and forms the bichloride of mercury, this compound reacting with another portion of the binoxide, and forming the oxychloride of mercury, which is left undissolved. To procure the hypochlorous acid in the gaseous form, Balard put a portion of its solution, highly concentrated, into a glass tube previously filled with mercury, and introduced successive fragments of dry nitrate of lime, which combined with the water, the acid then assuming the gaseous form. In this condition it is of a greenish-yellow colour, and resembles chlorine. It must be operated with cautiously, as it explodes when slightly heated.

555. The solution or aqueous hypochlorous acid is a transparent liquid of a yellowish colour, and a very penetrating odour. It

decolorizes powerfully animal and vegetable colouring matters, and is considered the active ingredient in bleaching powders or alkaline compounds of chlorine. The strong solution acts powerfully on the skin. It is decomposed with extreme facility when the rays of the sun act directly upon it, and also by agitation with fragments of glass and other similar substances. It is also decomposed slowly from the reaction of its elements, especially when exposed to light.

. 556. Hypochlorous acid is also particularly distinguished as an oxidating agent, converting sulphur, phosphorus, iodine, and bromine into sulphuric, phosphoric, iodic, and bromic acids.

SECT. II.—CHLOROUS ACID ; *(Quadroxide or Peroxide of Chlorine).*

Symb. O^4Cl, *or* $\cdot$: Cl.   *Eq. by W.* 67.5 (O 32 + 35.5 Cl.) ; *Eq. by volume* ⊡ *(two measures)* ; *Sp. gr.* 2.361 ; *weight of* 100 *cubic inches* 72 *grains.*

557. This is another gas which must be prepared with the greatest caution, and only in small quantities at a time ; it will be better for the beginner to pass on to the succeeding experiments, and defer preparing it till he shall have become more familiar with chemical manipulation, if he is left entirely to his own resources in conducting the process. It has the same general properties as euchlorine, but has a deeper colour, explodes with much more violence, and at a lower temperature ; every two measures(one equivalent)expanding to three measures, one of which is chlorine (one equivalent), while the other two consist of oxygen (four equivalents).

558. Instead of preparing a considerable portion of gas in a retort, which is very dangerous, a sufficient quantity to shew the facility with which it may be exploded may be obtained by putting a few drops of sulphuric acid on a grain or two of the chlorate of potassa at the bottom of a glass-tube, and holding it over a spirit-lamp when the deep colour of the glass indicates that the tube is full, or introducing a bent wire previously heated. (Faraday.) The tube I. generally employ is made of light green glass, very stout, about three inches long, and half

an inch in diameter. No cork is put in. The tube should be under a shade of wire-gauze, so as to retain all the broken pieces of 'glass should it give way. A stout glove ought to be put on the hand in which it is held, and it should be placed horizontally before the flame of the lamp, and then the middle of the tube is to be brought at once within the flame. The explosion is very loud, and a flash of light is at the same time perceived ; the precautions mentioned must be carefully attended to, as I have repeatedly seen a tube about the same size blown to pieces, notwithstanding the small quantity of gas which it contained.

559. To understand the theory of the process, it must be recollected that chloric acid is composed of five equivalents of oxygen and one of chlorine, so that it may be regarded as a compound of one equivalent of chlorous acid and one of oxygen. Four equivalents of sulphuric acid decomposing two of the chlorate of potassa, two of bisulphate of potassa are formed, and two of chloric acid are disengaged ; these react on another equivalent of chloric acid in combination with potassa, losing one equivalent of oxygen each, and being converted into chlorous acid, while the oxygen combines with the other equivalent of chloric acid and forms perchloric acid, which still remains united with the potassa. The following diagram gives a clearer view of the latter part of this complicated action.

Fig. 156.

Before Decomposition.   *After Decomposition.*

	Chlorous A. 67.5	67.5 Chlorous Acid.
2 Equivalents of	Chlorous A. 67.5	67.5 Chlorous Acid.
Chloric Acid,	Oxygen ..... 8.	
	Oxygen ...... 8.	
Chloric Acid, ...	75.5	91.5 Perchloric Acid.
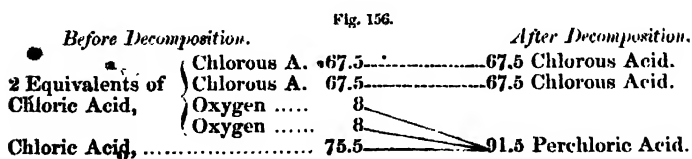
In the annexed symbols, the sulphuric acid and potassa are also represented.

$3 (::Cl \cdot K) \& 4 :S = \cdot ::Cl \cdot K \& 2 (2 :S + \cdot K) \& 2 \cdot :Cl.$
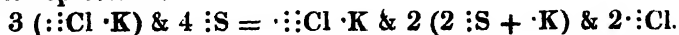
560. Chlorous acid has an aromatic smell, and none of the peculiar odour of chlorine. It promotes oxidation in the same manner as the hypochlorous acid. It is not affected at common temperatures by any of the simple inflammables except phosphorus, which inflames and decomposes it, burning brilliantly afterwards in the mixture of chlorine and oxygen that remains.

561. It is even capable of inflaming phosphorus under water,

which may be easily done by putting 30 or 40 grains of the chlorate of potassa into a long narrow glass, throwing in a few grains of phosphorus cut into thin slices, filling it with coltl water, and pouring sulphuric acid on the chlorate through a funnel that reaches to the bottom of the glass ; small quantities of acid must be added at a time. The chlorous acid is disengaged, inflaming the phosphorus as it rises through the water. The funnel must reach to the bottom of the glass, and be drawn out at the blowpipe so that the acid shall escape from it in a very slender stream or only by a few drops at a time ; it ought also to be filled with acid before it is put into the water, otherwise the sulphuric acid will not escape in a concentrated form. The offensive fumes that are evolved must be cautiously avoided ; for this purpose, the glass may be put in a plate or basin of water, and a glass shade put over it ; or it may be placed near any ventilating aperture, where the fumes may be rapidly withdrawn.

562. It combines with salifiable bases, producing salts, which are easily decomposed, passing into metallic chlorides and chlorates, one portion of the chlorous acid losing oxygen, which is transferred to another and forms the chloric acid of the chlorate produced.

EUCHLORINE.

563. A mixture of chlorine and chlorous acid, formed by the action of aqueous hydrochloric acid on the chlorate of potassa, has long been known by the name of EUCHLORINE, applied to it by Sir H. Davy who discovered it. This gaseous mixture possesses the properties of the chlorous acid, but in a comparatively feeble degree, the acid being diluted with a large quantity of chlorine. It has been termed *protoxide of chlorine*, a designation that must now be withdrawn, but as it is frequently prepared for experimental purposes, it may still be conveniently considered under the title of Euchlorine.

564. Euchlorine is prepared by pouring twelve parts of hydrochloric acid, diluted with an equal weight of water, on five parts of the chlorate of potassa (50 or 100 grains will be quite sufficient) ; applying a very gentle heat by a small spirit-lamp, and

collecting the gas that is disengaged at the mercurial trough. Great care ought to be taken in preparing this gas, as it explodes violently when exposed to a moderate heat, though no other gas be mixed with it ; the spirit-lamp should be held immediately below the retort, so as not to play on its sides, and the heat be such that the gas comes slowly away, producing a very moderate effervescence.

565. This gas is often collected in small bottles or tubes by displacement, in the manner described in 273, page 89. The deep colour of the gas indicates when the bottles in which it is collected are full.

566. Euchlorine is formed in this process by the mutual action of the hydrochloric and chloric acids. One part of the hydrochloric acid employed combines with the potassa of the chlorate of potassa, and disengages chloric acid, a compound of chlorine and oxygen ; another portion of the hydrochloric acid (which is composed of chlorine and hydrogen), reacts on the chloric acid in its nascent state, the hydrogen taking away one eq. of its oxygen, while the chlorine of the hydrochloric acid is liberated, along with chlorous acid from the chloric acid.

Symb. HCl & ::Cl = ·H & Cl & ·: Cl.

567. The free chlorine that the euchlorine always contains is disengaged in various proportions, according to the proportions in which the hydrochloric and chloric acids react on each other. When a great excess of strong hydrochloric acid is mixed with the chlorate of potassa, the chloric acid loses all its oxygen, and nothing but chlorine gas is disengaged. If one equivalent of chloric acid and five of hydrochloric acid mutually decompose each other, five equivalents of water will be formed, and six of chlorine disengaged.

Symb. 5 (HCl) & ::Cl = 5 ·H & 6 Cl.

568. Euchlorine has a rich greenish-yellow colour ; its odour resembles that of burned sugar. It destroys the vegetable colours, and is absorbed in considerable quantity by water, which can take up about ten times its volume.

569. Introduce a red-hot iron wire bent at one end, or a lighted candle, into a strong tube or detonating bottle filled with euchlorine ; an explosion immediately takes place, and a flash of light is at the same time perceived. The detonation arises solely from the separation of the elements of the chlorous

acid, in which they exist in a condensed state. If the explosion be caused by a combustible substance, it sometimes continues to burn afterwards in the mixed gases.

570. Phosphorus takes fire in this gas. With hydrogen a detonating mixture is formed ; the mixture must be inflamed by an electric spark, or a lighted match ; the products are water and hydrochloric acid.

SECT. III.—CHLORIC ACID.

Symb. O⁵Cl *or* ::Cl. *Eq. by W.* 75.5 (*Oxygen* 40 + 35.5 *Chlorine*).

571. This acid was at one time termed the Hyperoxymuriatic acid, from the opinion that it was composed of muriatic acid and oxygen, but it is now regarded as a compound of chlorine and this element.

572. To prepare chloric acid, sulphuric acid diluted with ten or twelve times its weight of water is added to a weak solution of the chlorate of baryta, as long as it gives any precipitate, taking care not to add an excess. The precipitate which falls is sulphate of baryta, and the chloric acid remains in solution.

573. The chlorate of baryta is prepared by transmitting a current of chlorine through a solution of baryta in water, placing it in one of the bottles of Woulfe's apparatus, (Fig. 101, p. 90). Hydrochlorate of baryta is formed at the same time, and till the discovery of hypochlorous acid, it was usually considered that chlorates and hydrochlorates of the bases employed, were the sole products of the action of chlorine upon water and an alkali or earth. But it is now ascertained that hydrochlorates and hypochlorites are formed in the first instance, part of the chlorine taking hydrogen, and another oxygen, from the decomposed water ; and that the chlorate is formed subsequently, by the decomposition of the hypochlorite, nine eqs. of this salt being resolved into one eq. of chlorate of baryta, eight of chloride of barium, and twelve of oxygen.

Symb. 9 (·Cl·Ba) = ˙Cl·Ba & 8 (ClBa) & O¹².

574. The decomposition of the hypochlorite takes place principally when the solution is heated to the boiling point. The chloride of barium in solution may be considered synonymous

with the hydrochlorate of baryta, into which it passes by decomposing one eq. of water.

*575. The hydrochlorate of baryta is separated from the chlorate by boiling the solution with phosphate of silver, phosphate of baryta and chloride of silver being formed by double decomposition, both of which are insoluble, while the chlorate of baryta remains in solution.

576. Instead of preparing chlorate of baryta and decomposing it by sulphuric acid to obtain chloric acid, which is not applied to any particular use in its free state, it will be more interesting to the beginner to prepare some chlorate of potassa, the most important of the salts of this acid, by transmitting chlorine through a solution of caustic potassa in the same manner as in the preparation of the chlorate of baryta. The reaction that ensues is exactly the same in both cases, hydrochlorate and chlorate of potassa being formed in the present instance. The chlorate is deposited in crystals from the solution, but the hydrochlorate, being more soluble, remains dissolved. Instead of using caustic potassa, a strong solution of the carbonate is generally employed. The siliceous matter which the common carbonate always contains is deposited first, rendering the liquid cloudy, and mixing with the chlorate of potassa; it is separated by dissolving the crystals of the chlorate in the smallest quantity of hot water that will take them up, which deposits the salt in crystals again as it cools. The carbonic acid of the carbonate is separated with effervescence.

577. Five parts by weight of the common binoxide of manganese with a proper proportion of hydrochloric acid (529, p. 167), may be taken for every eight parts of the carbonate of potassa.

578. Chloric acid reddens the vegetable blues, is decomposed by a number of substances which have a great affinity for oxygen, and forms an important class of salts, all of which are decomposed by heat, and distinguished by the violent action that takes place when they are exposed to heat along with inflammable substances. With some inflammable bodies, the salts of chloric acid detonate at natural temperatures by friction or percussion. Its solutions are not precipitated by a solution of the nitrate of silver.

Sect. IV.—Perchloric Acid.

Symb. $\cdot\ddot{}$Cl.   *Eq. by* $\dot{W}$. 91.5 (O. 56 + 35.5 Cl).

579. Heat aqueous sulphuric in an evaporating basin, and add carefully, in small successive portions, and in the finest powder, an equal weight of *very* dry chlorate of potassa. The products are perchlorate of potassa, bisulphate of potassa, and chlorous acid, which is evolved, the same reaction taking place as is described in the section on chlorous acid.

580. Remove by cold water the bisulphate of potassa (a very soluble salt) from the perchlorate, which is very sparingly soluble (requiring sixty-five times its weight of cold water for solution). Dissolve the perchlorate in boiling water, and purify it by crystallization. Then mix one part of water, four of aqueous sulphuric acid, and eight of the perchlorate, in a glass-retort, and apply heat. The perchloric acid, and part of the water, are then distilled over, and may be condensed in a receiver.

581. By mixing the solution with aqueous sulphuric acid, and distilling a second time, it has been procured in the solid form.

582. Perchloric acid is particularly distinguished by the very sparing solubility of the salt it forms with potassa. Its concentrated solution has a specific gravity of 1.65, and emits fumes when exposed to the air. It is not so prone to decomposition as the other compounds of chlorine and oxygen, and is not affected by sulphuric or hydrochloric acids.

Sect. V.—Hydrochloric or Muriatic Acid.

Symb. HCl.   *Eq. by* W. 36.5 *(Chlorine* 35.5 *+* 1 *Hydrogen)* ; *by volume* ⊡ *(two measures).* *Specific gravity* 1.256.   *Weight of* 100 *c. i.* 38.97 *grains.   It is liquefied by a pressure of* 40 *atmospheres at* 50°.   *Water absorbs* 480 *times its bulk of this gas.*

583. This important compound exists always in the gaseous

state at natural temperatures and under ordinary pressure. The term *muriatic acid* is commonly applied to a compound of it and water, also called *Spirit of Salt, Marine Acid*, being usually prepared by distillation from common salt (chloride of sodium) and sulphuric acid.

584. The best process for the preparation of the common liquid hydrochloric acid is that adopted by the Edinburgh College. Common salt is exposed for an hour or two to a red heat in an earthen vessel, to decompose any nitrates which it may contain (a small quantity of these salts being occasionally found in it). It is then mixed in a glass-retort with an equal weight of sulphuric acid, previously diluted with a third of its weight of water, and allowed to cool before using it, pouring the acid upon the salt by a long funnel (Fig. 55, p. 34). The retort is then placed in a sand-bath, and a receiver adapted to it, containing water equal in weight to two-thirds of the salt employed. The materials should not occupy more than a third of the body of the retort, as they are apt to boil over when exposed to heat. The furnace is kindled after every thing has been properly adjusted, and the distillation is continued to dryness ; the receiver is kept cold, and the apparatus arranged in the manner represented in Fig. 77, p. 60. When the atmospheric air in the retort and receiver has been expelled, which usually takes place a short time after the mixture begins to boil, the receiver may be luted to the neck of the retort with a little clay, taking care always to keep it sufficiently cold by a constant stream of water. One equivalent of sulphuric acid (49.1) is capable of decomposing one equivalent of chloride of sodium (59), and giving an equivalent of hydrochloric acid ; but Dr Hope found that when equal weights are employed, the decomposition, as it is usually effected, is more complete, and a larger quantity of hydrochloric acid more easily procured. The acid gas produced by the action, and the water previously mixed with the materials, are condensed in the receiver, and considerable heat is produced not only by the condensation of the watery vapour, but also by the combination of the hydrochloric acid gas with the water in the receiver.

585. The specific gravity of the acid compound collected in the receiver would be above 1.18, and would contain 38 per cent. of dry hydrochloric acid, were all the water added to the sulphuric acid to be collected in the receiver, and all the hydro-

chloric acid which the salt can afford to be condensed by the water. The specific gravity of the acid usually sold is 1.17, and it contains about 34 per cent. of dry acid.

586. In this process, each equivalent of hydrochloric acid is formed by one equivalent of the chlorine of the chloride combining with the hydrogen of the water in the common sulphuric acid. The sodium takes the oxygen thus liberated and forms soda, with which the sulphuric acid at the same time unites, and is converted into sulphate of soda. The excess of sulphuric acid (which is not represented in the following diagram) combines with part of the sulphate of soda and forms a bisulphate.

Fig. 157.

Before Decomposition.		After Decomposition.
49.1 Aqueous Sulphuric Acid	Hydrogen...... 1. Oxygen......... 8. Dry Acid.......40.1	.36.5 Hydrochloric Acid.
59 Chloride of Sodium	Chlorine.......35.5. Sodium.........23.5	71.6 Sulphate of Soda.

Symb. ·H !S & Cl Na = HCl & !S ·Na.
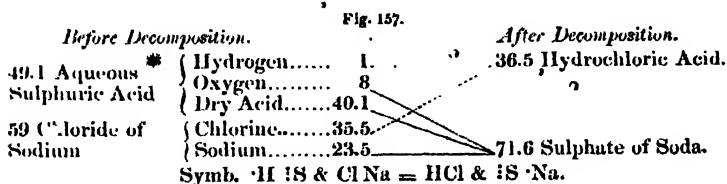
587. Dilute some of the acid with an equal bulk of water, and add a drop or two of a solution of the hydrochlorate of baryta; if any precipitation take place, it contains sulphuric acid. This may be separated by a second distillation with a small quantity of the chloride of sodium, condensing it in water as before. When the process is carefully conducted, the hydrochloric acid is never contaminated with sulphuric acid.

588. Hydrochloric acid gas may be formed by detonating a mixture of equal measures of chlorine and hydrogen; the bottle should be filled half full of hydrogen first, and then filled up with chlorine, corking it immediately to prevent the absorption of any of the chlorine by the water. A lighted match is then applied in the usual manner; the mixture detonates with flame and a loud report, but no condensation attends the combination, two measures of hydrochloric acid gas being formed. Pour an infusion of litmus into the bottle immediately after the detonation; it will be reddened by the hydrochloric acid; if it had been poured in before the combination was effected, the chlorine would have rendered it colourless.

589. Fill the detonating bottle again with hydrogen and chlorine in the same manner and in the same proportions, cork it,

and expose it to the direct rays of the sun. A detonation takes place, and if the cork be not forced out, the hydrochloric acid gas will be completely absorbed on taking it out under water. If the mixture be kept in the dark, no action takes place, at least for a great length of time; in the shade, the chlorine and hydrogen combine slowly without detonation.

590. When hydrochloric acid is required in the gaseous form, it must be collected in jars or bottles over the mercurial trough, as it is instantly absorbed in large quantity by water. The easiest method of obtaining it is by exposing a strong solution of hydrochloric acid in water (common liquid muriatic acid) to a gentle heat in a small tubulated retort capable of containing three or four ounces; it may be filled half full, and a spirit-lamp held in the hand will be found the most convenient method of applying the heat. Hydrochloric acid gas is soon disengaged abundantly, and may be collected after the air has been expelled from the retort; no water is distilled over along with it till a considerable portion of gas has been expelled. A sufficient quantity should be collected at once for all the experiments it is intended to perform with it.

591. When the student has no mercurial trough, he may collect the hydrochloric acid gas by displacement in the manner represented in Fig. 100, p. 89.

592. Hydrochloric acid gas has an acrid, pungent, and suffocating odour, and has a strong acid taste, even when combined with a large quantity of water. It is transparent and colourless, produces fumes when mixed with the air, combining with the watery vapour which it contains; and it cannot support combustion or respiration.

593. Hydrochloric acid gas has a very great affinity for water, which can absorb 480 times its bulk of this gas. Considerable heat is produced by the combination, and the specific gravity of the resulting liquid is 1.21.

594. Take a long tube or bottle filled with the acid gas at the mercurial trough, close it with the thumb or finger, transfer it to a basin of water coloured blue by an infusion of cabbage or litmus, and remove the finger under the surface of the water: the gas is immediately condensed, the coloured water is forced up into the tube with explosive violence by the pressure of the atmosphere, and reddened at the same time by the acid. If any

common air should be mixed with the gas, the absorption goes on more slowly, and the air remains in the tube.

595. Fill a small test tube with water, and introduce a little into a jar of hydrochloric acid gas over the mercurial trough (see 267, page 88); observe the large quantity of gas it condenses, which is indicated by the rising of the mercury.

596. Put a piece of ice into another jar; it is melted almost immediately, and a solution of hydrochloric acid is formed.

597. Take 300 grains (or any other known quantity) of the acid procured by distillation in the manner described, dilute it with an equal quantity of water, and drop into it fragments of marble from a given weight of this substance, till it will not dissolve any more. Then ascertain the quantity of marble dissolved, by weighing what may still remain undissolved in the liquid, first washing it with water, and drying it. Then calculate the quantity of dry hydrochloric acid which it contains, allowing 36.5 grains of dry acid for every 50.62 grains of marble dissolved; for 36.5 parts (one equivalent) of dry hydrochloric acid render soluble 50.62 parts of marble ($=$ carbonic acid $22.12 + 28.5$ lime). combining with the lime and disengaging the carbonic acid.

598. Fill a long tube half full of strong liquid hydrochloric acid, and pour water gently over it till the tube is full, then close the mouth with the finger rubbed over with a little wax lute, and invert it till the two fluids are completely mixed. Heat is evolved, and when the diluted acid is cooled, it will be found to occupy a smaller volume than the liquids before they were combined.

599. Strong liquid hydrochloric acid is transparent and colourless when perfectly pure, emits copious fumes on exposure to the air, boils at 110°, giving off hydrochloric acid gas, and freezes when exposed to a very low temperature.

600. It has usually a light greenish-yellow colour, from the presence of a small quantity of chlorine or chloride of iron. The chlorine is produced by the presence of nitric acid. which reacts on part of the hydrochloric acid; the nitric acid is disengaged from some nitrates mixed with the salt, by the sulphuric acid used in the process. The iron of the chloride is derived from some impurities in the materials employed, or from the iron vessels in which the acid is prepared on the large scale. Chlorine

may be occasionally detected by the smell, or by gold leaf, which it speedily dissolves, but on which pure hydrochloric acid has no action. To detect the iron, an excess of ammonia must be added to a small portion of the acid diluted with five or six times its bulk of water, when any iron that may be present will be precipitated. When hydrochloric acid is coloured by free chlorine, it may be rendered colourless by adding a few fragments of tin, which combines with the chlorine. The hydrochloric acid gas may then be redistilled. The presence of iron and any sulphuric acid may be avoided by passing the gas through a small quantity of water in the first bottle of a Woulfe's apparatus.

601. The following table (abridged from one in Dr Ure's Dictionary), shews the quantity of dry acid in common hydrochloric acid of different densities.

Table of Liquid Hydrochloric Acid by Dr Ure.

Specific Gravity.	Dry Acid in 100 parts.	Specific Gravity.	Dry Acid in 100 parts.	Specific Gravity.	Dry Acid in 100 parts.	Specific Gravity.	Dry Acid in 100 parts.
1.2000	40.777	1.1515	30.528	1.1000	20.388	1.0497	10.194
1.1982	40.369	1.1494	30.174	1.0980	19.980	1.0477	9.786
1.1964	39.961	1.1473	29.767	1.0960	19.572	1.0457	9.379
1.1946	39.554	1.1452	29.359	1.0939	19.165	1.0437	8.971
1.1928	39.146	1.1431	28.951	1.0919	18.757	1.0417	8.563
1.1910	38.738	1.1410	28.544	1.0899	18.349	1.0397	8.155
1.0893	38.330	1.1389	28.136	1.0879	17.941	1.0377	7.747
1.1875	37.923	1.1369	27.728	1.0859	17.534	1.0357	7.340
1.1857	37.516	1.1349	27.321	1.0838	17.126	1.0337	6.932
1.1846	37.108	1.1328	26.913	1.0818	16.718	1.0318	6.524
1.1822	36.700	1.1308	26.505	1.0798	16.310	1.0298	6.116
1.1802	36.292	1.1287	26.098	1.0778	15.902	1.0279	5.709
1.1782	35.884	1.1267	25.690	1.0758	15.494	1.0259	5.301
1.1762	35.476	1.1247	25.282	1.0738	15.087	1.0239	4.893
1.1741	35.068	1.1226	24.874	1.0718	14.679	1.0220	4.486
1.1721	34.660	1.1206	24.466	1.0697	14.271	1.0200	4.078
1.1701	34.252	1.1185	24.058	1.0677	13.863	1.0180	3.670
1.1681	33.845	1.1164	23.650	1.0657	13.456	1.0160	3.262
1.1661	33.437	1.1143	23.242	1.0637	13.049	1.0140	2.854
1.1641	33.029	1.1123	22.834	1.0617	12.641	1.0120	2.447
1.1620	32.621	1.1102	22.426	1.0597	12.233	1.0100	2.039
1.1599	32.213	1.1082	22.019	1.0577	11.825	1.0080	1.631
1.1578	31.805	1.1061	21.611	1.0557	11.418	1.0060	1.224
1.1557	31.398	1.1041	21.203	1.0537	11.010	1.0040	0.816
1.1536	30.990	1.1020	20.796	1.0517	10.602	1.0020	0.408

602. The most delicate test of hydrochloric acid is a solution of the nitrate of silver, which gives a copious curdy precipitate of the chloride of silver, the hydrogen of the acid combining at

the same time with the oxygen of the oxide. Chlorine, indeed, gives a similar precipitate, but its action on blue vegetable colouring matter distinguishes it sufficiently from the acid, chlorine rendering it colourless, while hydrochloric acid renders it of a bright red colour.

603. Hydrochloric acid combines with the salifiable bases, and forms an important class of salts termed hydrochlorates. They are, in general, decomposed by heat, the hydrogen of the acid uniting with the oxygen of the oxide, the resulting products being water and a metallic chloride. They are decomposed also by sulphuric acid.

604. In solutions prepared by the action of hydrochloric acid on a fixed alkali, earth, or common metallic oxide, the elements may be arranged so as to be in the state of a hydrochlorate of the oxide, or a chloride of the metal and water. Thus, common salt in solution may be hydrochlorate of soda, or chloride of sodium and water.

Symb. HCl ·Na = Cl Na & ·H.

Sect. VI.—Quadrochloride of Nitrogen.

Symb. Cl⁴N. *Eq. by W.* 156.2 (*Chlorine* 142 + 14.2 *Nitrogen.*)

605. This compound detonates with great violence when touched with many inflammable substances, or exposed to heat; many accidents, attended with very serious consequences, have taken place during its preparation.

606. It is prepared by inverting a jar or wide-mouthed bottle (capable of containing about 12 or 14 ounces) full of chlorine over a dilute solution of the hydrochlorate of ammonia, made by dissolving an ounce of the salt in ten or twelve ounces of water; the bottle is placed on a very strong shallow leaden cup, which rests on a deep plate containing the solution previously heated to the temperature of 90°. One portion of the chlorine takes the hydrogen of the ammonia, forming hydrochloric acid, and the other, combining with the nitrogen, is converted into the quadrochloride, which collects in the form of an oil on the surface of the liquid, and drops through it into the leaden cup; an additional quantity of the solution must be ready to fill up the

plate as the absorption of the chlorine proceeds. Great care must be taken not to shake the bottle, and any gas-lute or fatty matter adhering to it must be removed by washing it with a dilute solution of potassa before it is filled with chlorine. When the oil has fallen into the leaden cup, the bottle is carefully moved from the cup, which is taken cautiously away.

607. The liquid remaining above the quadrochloride of nitrogen in the cup is withdrawn by dipping small pieces of bibulous paper into it. On touching the quadrochloride with a drop of olive-oil at the end of a stick, which should be at least two or three feet long, a loud explosion takes place, though the quantity of the quadrochloride should not exceed the bulk of a pea. It is resolved at the same time into chlorine and nitrogen. The manner in which inflammable substances act when they cause an explosion with it has not been precisely ascertained ; it is supposed that the chlorine takes hydrogen from many of the inflammable substances with which the chloride is touched, and is converted into hydrochloric acid gas, the nitrogen also assuming suddenly the gaseous form.

608. Its odour is extremely penetrating and almost insupportable, affecting the eyes very much on leaning over it even for a second or two : at natural temperatures it volatilizes rapidly, and explodes when heated to 200°.

Sect. VII.—Nitro-Muriatic Acid. (Aqua Regia.)

609. There is no chemical compound of nitric and hydrochloric acids (or at least it can exist only at low temperatures), these two substances decomposing each other and forming chlorine, water, and nitrous acid. Nitric acid may be regarded as a compound of nitrous acid and oxygen, and in the following diagram its composition is stated in this manner, that the nature of the reaction which takes place between it and hydrochloric acid may be more easily perceived :

Fig. 158.

Before Decomposition.		After Decomposition.
36.5 Hydrochloric Acid	{ Chlorine...... 35.5 ... ... 35.5 Chlorine.	
	{ Hydrogen ... 1__ _____	
54.2 Nitric Acid	{ Oxygen ...... 8_____ 9 Water.	
	{ Nitrous Acid 46.2_____46.2 Nitrous Acid.	

This compound, then, though still called the Nitro-Muriatic Acid (known also by the name of *Aqua Regia*, from its power of dissolving gold), is 'in reality composed of chlorine, water, and nitrous acid; its characteristic properties depend on the presence of free chlorine.

610. It is prepared usually by mixing two measures of nitric acid with one of hydrochloric acid, but various proportions are employed for different purposes, as an excess of nitric or hydrochloric acid may be required along with the chlorine; 100 parts of common hydrochloric acid, specific gravity 1:18, and 74 of nitric acid, specific gravity 1.48, are the proportions of the two acids necessary for decomposing each other in the manner represented in the diagram. In some operations a smaller quantity of nitric acid may be sufficient to decompose the hydrochloric acid, more oxygen being withdrawn in this instance from the nitrogen of the nitric acid. The nature of the reaction, the deep red colour which the liquid assumes, and the disengagement of chlorine, may be easily seen by mixing half an ounce by measure of hydrochloric acid with an ounce of the nitric, and exposing the mixture to a gentle heat in a flask.

SECT. VIII.—COMPOUNDS OF CHLORINE WITH BINOXIDE OF NITROGEN, SULPHUR, PHOSPHORUS, CARBON, HYDRURET OF CARBON, CARBONIC OXIDE, AND BORON.

611. CHLORONITROUS GAS.—This compound is formed when chloride of sodium is mixed with concentrated nitric acid, which is added in sufficient quantity to moisten it. It has a reddish-yellow colour, and was discovered by Mr E. Davy, who regards it as a compound of equal volumes of chlorine and binoxide of nitrogen.

612. The sodium of the common salt attracts oxygen from part of the nitric acid, and becomes soda, while binoxide of nitrogen is evolved and attaches itself to the chlorine of the salt. The soda combines with a portion of undecomposed nitric acid.

613. DICHLORIDE OF SULPHUR is prepared by transmitting chlorine over flowers of sulphur in a glass-vessel moderately heated. It is mixed at first with an excess of sulphur, from which it is separated by distillation. It is a reddish-coloured liquid,

easily volatilized, and emits very acrid irritating fumes.   It de-composes water, alcohol, and ether, a portion of sulphur being deposited, and the remaining sulphur being converted into sul-phurous and sulphuric acids by the oxygen which it takes from these substances, the chlorine at the same time uniting with hy-drogen, and forming hydrochloric acid.

614. Dumas has described a chloride of sulphur which he pre-pared by using a great excess of chlorine.

615. The method of preparing the CHLORIDE OF PHOSPHORUS, termed more specifically the sesquichloride, and the only use to which it has been applied, are described in 377.   The PERCHLO-RIDE OF PHOSPHORUS is formed when phosphorus is introduced into chlorine.   Water and the perchloride mutually decompose each other, the chlorine taking hydrogen, and producing hydro-chloric acid, while the phosphorus, combining with the oxygen, is converted into phosphoric acid.

616. HYDRO-CARBURET OF CHLORINE is prepared by mixing two measures of chlorine with one of olefiant gas, and leaving the mixture over water.   A slow combination ensues, and a few drops of an oily liquid are formed, which must be washed with water, mixed with some chloride of calcium to retain any water that may adhere to it, and purified by distillation.   Its taste is sweet ; it boils at about 150°, and is completely decomposed by a red heat.

617. By subjecting this compound repeatedly to the action of chlorine gas while exposed to the rays of the sun, Dr Faraday succeeded in obtaining a compound of chlorine and carbon, the hydrogen being removed and converted into hydrochloric acid. It has received the name of PERCHLORIDE OF CARBON.   For the details of the process for preparing this compound, I must re-fer to Dr Faraday's paper in the Philosophical Transactions for 1821.   When its vapour is passed through a red-hot porcelain tube, a large quantity of chlorine is disengaged, and a liquid is obtained, composed of one equivalent of carbon and one of chlo-rine, the PROTOCHLORIDE OF CARBON.   Another compound, the DICHLORIDE OF CARBON, called also SUBCHLORIDE OF CARBON, or BICARBURET OF CHLORINE, has been described.   It contains two eqs. of carbon, and one of chlorine.

618. CHLOROCARBONIC ACID is a compound of chlorine and carbonic oxide, discovered by Dr John Davy ; it has been called

Phosgene Gas, from being formed by the action of light on the mixed gases. It is transparent and colourless, reddens litmus paper, combines with ammonia, and is decomposed by water, when carbonic and hydrochloric acids are produced, the hydrogen of a portion of water combining with the chlorine, and the oxygen with the carbonic oxide. It is also decomposed by tin, zinc, antimony, and other metals, when they are heated in it. The metal combines with the chlorine, and liberates the carbonic oxide.

619. Terchloride of Boron. To prepare this gas, heat boron gently in a glass-tube where it may be exposed to a current of chlorine, and collect the terchloride thus formed in a tube or jar at the mercurial trough. It is contaminated at first with an excess of chlorine, which is soon condensed by the mercury.

620. Terchloride of boron has a great attraction for moisture, and is condensed rapidly by water, being at the same time decomposed, and producing with the elements of the water, hydrochloric and boracic acids.

$$Cl^3 B \& 3 \cdot H = 3 HCl \& :B.$$
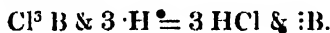
CHAP. X.—IODINE.

Symb. I. *Eq. by W.* 126.5 ; *by volume* □. *Sp. gr. of solid iodine* 4.948 ?* *Sp. gr. of the vapour of iodine* 8.717. *W. of* 100 *c. i.* 270.3 *grains. It requires* 7000 *parts of water for its solution, but is much more soluble in alcohol and in ether. It volatilizes at natural temperatures, melts at* 227°, *and sublimes at* 350°.

621. Iodine is a substance that bears a great resemblance to chlorine in all its chemical relations ; it was discovered by M. Courtois in 1812. It is obtained from the ashes of incinerated marine plants.

622. The process usually followed for the preparation of iodine was proposed by Dr Ure. The liquid that remains after

* 3.0844, according to Dr Thomson.

most of the saline matter has been extracted from kelp * is
heated to the temperature of 230°, and poured into a stone-ware
basin (which should not be more than half full) : then one part
by measure of sulphuric acid, previously diluted with an equal
bulk of water, is mixed with every eight parts by measure of
the liquid employed.   A brisk effervescence immediately takes
place, a quantity of sulphur is at the same precipitated, crystals
of the sulphate of soda are deposited when the mixture is cold,
and hydriodic acid remains in solution.   .

623. The salts which this fluid contains are composed prin-
cipally of soda, combined with hydrosulphuric, carbonic, sul-
phurous, and hydriodic acids, all of which are separated by the sul-
phuric acid, which combines with the soda and forms the sulphate
that is afterwards crystallized.   The carbonic acid and part of
the hydrosulphuric and sulphurous acids are disengaged, and pro-
duce the effervescence ; the remainder of the latter compounds
mutually decompose each other, the hydrogen of the one com-
bining with the oxygen of the other, while the sulphur of both is
precipitated.   The impure hydriodic acid which remains in the
liquid, is separated from the sulphur by filtration through paper.

624. In the last stage of the process, the iodine is obtained
by mixing 1000 grains of the binoxide of manganese with every
12 ounces, apothecaries' measure, of the filtered liquid, in a
glass-retort (capable of containing at least
24 ounces when quite full), and applying
heat.   The iodine is to be collected in a re-
ceiver kept cold in the usual manner.   Dr
Ure recommends a glass-flask to be used,
and the iodine, which is deposited in small
crystals, to be condensed in a large globe or
receiver placed above it in the manner re-
presented in Fig. 159, interposing a disc of
wood (a tin plate does better), with a hole in
the centre, between the flask and the receiver, that the latter
may not be heated too much by the hot air ascending from the
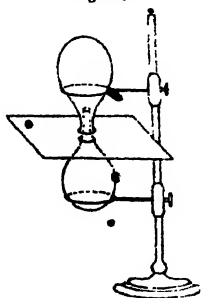
Fig. 159.

* Kelp is the term applied to the ashes of incinerated sea-weed prepared on
the coast of Scotland, and is used in large quantities by several of the soap-
manufacturers in this country, from whom the above liquid is generally pro-
cured.   In many soap-manufactories, the use of kelp has been entirely super-
seded by soda prepared from common salt.   .

chauffer. A mixture of cinders and charcoal gives a better fire for this purpose than either of them separately. When the globe becomes warm from the condensation of iodine and watery vapour, it must be removed, and another put in its place, washing out the iodine with a small quantity of water, that it may be ready to replace the other. When the prepared iodine liquor has been kept some weeks before it is used, sometimes little or no iodine is obtained on heating it with binoxide of manganese : in such cases I have found that the addition of a little caustic potassa causes the iodine vapours to appear in as large a quantity as if the liquid had been newly prepared. From 80 to 100 grains of pure iodine are obtained from the above quantity of liquid.

625. The theory of the process is similar to the theory of the preparation of chlorine from hydrochloric acid. Hydriodic acid is composed of one equivalent of hydrogen and one of iodine, and water, iodine, and hydriodate of manganese result from the mutual reaction of two equivalents of this acid and one of the binoxide of manganese. The following diagram gives a more precise view of the nature of the action which takes place :—

Fig. 160.

Before Decomposition.		After Decomposition.
27.5 Hydriodic Acid { Hydrogen 1.		.9 Water.
{ Iodine 126.5		126.5 Iodine.
127.5 Hydriodic Acid 127.5		
43.7 Binoxide of M. { Oxygen ... 8.		
{ Ox. Mang. 35 7		163.2 Hydriodate of M.

Symb. 2 HI & Mn = H & I & HI + Mn.

626. If, however, an excess of sulphuric acid be present in the liquid, which is generally the case, then all the hydriodic acid may be decomposed, sulphate of manganese being formed, and the oxygen disengaged from the binoxide uniting with the hydrogen of the hydriodic acid. • The details of the action have not yet been minutely investigated.

627. As the liquid directed to be used in the preceding process cannot be so easily procured now, many soap manufacturers using very little kelp, and obtaining the soda they require principally from other sources, a little pure hydriodic acid may be mixed with the binoxide of manganese in a small tube or glass-retort, to shew the action that takes place. Should the soda

N

liquid obtained from the manufacturer not have been prepared
from kelp alone, and contain, therefore, a different proportion
of hydriodic acid, a quantity of sulphuric acid different from
that mentioned in 622 must be employed.   The proportion re-
quired must be found out by operating on small quantities, and
observing in what proportion the most abundant products can be
obtained.

628. Iodine is a solid substance of a dark bluish-grey colour
and metallic lustre; when slowly sublimed, its vapour condenses
in rhomboidal plates.   It has a pungent odour, an acrid taste,
stains the skin of a deep brownish-yellow colour, and destroys
the vegetable colours. though it acts more feebly upon them than
chlorine.   With oxygen, hydrogen, nitrogen, sulphur, phospho-
rus, and the metals, it forms an important class of compounds,
similar in their general chemical relations to those which chlo-
rine forms with the same substances.

629. Put a few grains of iodine into a large glass-flask, and
expose it to a gentle heat.   The iodine is sublimed and forms a
rich violet-coloured vapour, which condenses in crystals as it
cools.

630. Boil a little iodine with five or six ounces of water in a
Florence flask.   The vapour of iodine rises along with the va-
pour of the water at 212°.

631. Cut three or four very thin pieces of phosphorus, place
them on a tin cup after they have been well dried, and throw a
little iodine upon them.   They combine. considerable heat is
produced, and part of the phosphorus is generally inflamed.   If
they be brought in contact in a small tube filled with mercury
and inverted in a cup of the same liquid, or at the mercurial
trough, they immediately combine, but no light is disengaged :
the light appears only when part of the phosphorus combines
with the oxygen of the air, being inflamed by the heat produced.

632. Make a strong solution of starch in boiling water, and
mix some iodine with it ; a compound of a very deep blue colour
is formed immediately.   Pour some boiling water upon it, and
the mixture becomes quite colourless.   Pour the colourless liquid
immediately, while still warm, into cold water : the blue tint of
the iodide of starch is in general restored, but if it be allowed
to cool slowly, the colour seldom returns.   Starch is the most
delicate test of iodine which we possess, and with this substance

one part of iodine may be detected in 450,000 of water. Drop a solution of starch into a solution of iodine and water, and observe the deep blue colour which is immediately produced, though this liquid can dissolve only $\frac{1}{7000}$dth part of its weight of iodine.

633. The best method of detecting minute proportions of iodine in solution was pointed out by M. Balard. The liquid suspected to contain it is mixed with a solution of starch, and sulphuric acid added in excess ; chlorine water is then poured over it : a blue band is perceived where the two liquids meet if any iodine be present, and though it may be very feeble, it is in general distinctly recognised on contrasting it with the liquids above and below. The sulphuric acid separates the hydriodic acid (for this is the form in which iodine usually exists) from any base with which it may be combined, and the chlorine, taking the hydrogen of the hydriodic acid, disengages its iodine, which immediately combines with the starch. The blue compound is produced solely by the combination of the starch with the free iodine ; hydriodic acid has no action on starch.

634. If the proportion of hydriodic acid in solution be not exceedingly small, part of the sulphuric acid reacts on it and disengages a portion of iodine, which immediately produces the characteristic blue colour with the starch, though no chlorine be added. To see this, dissolve a grain of the hydriodate of potassa in a few ounces of water, and pour a solution of starch into it, after adding a drop or two of sulphuric acid. If the solution of the hydriodate be strong, iodine vapour is disengaged on adding strong sulphuric acid ; Dr Fyfe found that this takes place also when the acid is added to a concentrated infusion of marine algæ in hot water. In these cases, while one portion of the acid combines with the salifiable base, the other yields oxygen to the hydrogen of the hydriodic acid, water and sulphurous acid being at the same time formed.

Symb. :S & III = :S & ·H & I.

635. Chlorine can generally liberate iodine from its combinations, without the aid of sulphuric acid, and enable it to affect starch in the usual manner. It is preferred, however, to operate in the manner described in par. 633.

636. In all these experiments for detecting iodine, cold water must be employed, as the blue compound of iodine and starch

is decomposed by hot water. Minute quantities also of the chlorine and sulphuric acid should be added at first, as an excess destroys the compound of iodine and starch.

637. Iodine is frequently employed in medicine and acts as a virulent poison when given in an over dose. The proper antidotes are large quantities of starch and other mucilaginous substances dissolved in water.

638. Iodine is frequently adulterated with a variety of substances from which it may be separated by sublimation. It is also often loaded with moisture, which may be removed by putting it into a cup or phial, and placing this in a larger phial or bottle containing dry chloride of calcium. The water associated with the iodine evaporates, and is abstracted from the moistened air by the chloride, the evaporation continuing till the water is in a great measure or entirely removed from the iodine.

Sect. I.—Iodic Acid.

Symb. ∷I.   *Eq. by W.* 166.5 *(Oxygen* 40 + 126.5 *Iodine.)*

639. Four compounds of iodine and oxygen have been described; viz. oxide of iodine, iodous acid, iodic acid, and periodic acid. The iodic is the most important: the qualities of the oxide and of iodous acid have not been so minutely ascertained; they were obtained by heating iodine with different quantities of oxygen gas.

640. Iodic acid may be prepared by a process pointed out by Sir H. Davy. Euchlorine, prepared by pouring 400 grains of hydrochloric acid, specific gravity 1.105, on 100 of the chlorate of potassa in a tube-retort, and applying a gentle heat (See par. 564), is conducted into a small thin glass receiver containing about 40 grains of iodine, a few pieces of chloride of calcium being put into the neck of the retort. An evolution of heat and light takes place when the euchlorine comes in contact with the iodine, one portion of which combining with the oxygen of the euchlorine, is converted into iodic acid, while the remainder unites with the chlorine, forming a compound which is easily separated from the iodic acid by a moderate heat.

641. Another process has been recommended by Mr Connell. It consists in boiling one part of iodine with five of the strongest nitric acid, in a tube fourteen or fifteen inches long; heat is applied to the lower part of the tube only, so that any undecomposed acid that is vaporized may return and act upon the iodine. Part of the iodine is volatilized from time to time, and condenses upon the upper part of the tube, from which it must be washed down with the acid liquid, or pushed down by a slip of glass.

642. Iodic acid is a white semitransparent solid, having a very acid astringent taste. It is decomposed when heated to 390. It is soluble in water and deliquescent, and reddens the vegetable blues. Its salts are termed iodates. Many of them may be prepared by the mutual action of their bases on water and iodine, the same reaction taking place that has been already described with respect to chlorine (573). They detonate with inflammable substances, and have the same general properties as the chlorates.

SECT. II.—PERIODIC ACID.

Symb. ⠒I.   *Eq. by W.* 182.5 *(Oxygen* 56 + 126.5 *Iodine).*

643. Mix solutions of soda and iodate of soda. Pass chlorine into the mixture in a Woulfe's apparatus till it absorbs no more, and then concentrate the solution by evaporation till a solid matter is deposited, the PERIODATE of SODA. In this operation, the chlorine unites with the sodium of the free soda, and its oxygen is transferred to the iodate of soda, producing the periodate.

644. The periodate is now to be dissolved in hot diluted nitric acid, and mixed with a solution of nitrate of silver. The mixture, if the solutions be of sufficient strength, deposits, while warm, crystals of an orange colour, which consist of the periodate of silver. By treating the periodate of silver with cold water, it is decomposed, and one-half of its acid removed in solution, all the silver being left with the remaining periodic acid in the form of a diperiodate of silver.

645. Periodic acid is similar to the perchloric acid in its

general chemical relations. Its solution, when concentrated by evaporation, yields crystals which are not affected by the air. When subjected to an increase of temperature, they are decomposed, part of the oxygen being expelled.

SECT. III.—HYDRIODIC ACID.

Symb. HI.   *Eq. by W.* 127.5 *(iodine* 126.5 + 1 *hydrogen).*   *Eq. by volume* ⊡ *(two measures).*   *Sp. gr.* 4.2 ; *W. of* 100 *c. i.* 136.24 *grains. Water absorbs a very large quantity of this gas. Sp. gr. of common liquid hydriodic acid (hydriodic acid gas dissolved by water)* 1.5 ?

646. Hydriodic acid gas is formed by the action of one part of phosphorus with ten of iodine and four of water. The iodine and water are put first into a very small glass-retort or flask, the phosphorus added, and a gentle heat applied with a spirit-amp. In a very short time, a brisk reaction commences, a slight explosion generally taking place within the retort from the heat produced inflaming a portion of phosphorus, and also from the disengagement of a little phosphureted hydrogen. Dense vapours are at the same time disengaged, and the hydriodic acid gas may be collected by displacement (Fig. 100 page 89) after these have been expelled. Water absorbs it as rapidly as hydrochloric acid gas, and it cannot be kept long over mercury. as this metal begins to act upon it whenever they come into contact, the mercury combining with the iodine, and leaving hydrogen gas. Phosphureted hydrogen is disengaged in considerable quantity towards the end of the operation ; when it begins to come, it is recognised by the acid gas with which it is mixed producing with the air a whiter coloured vapour than previously ; the process should then be stopped to prevent it from accumulating. Fifty or a hundred grains of iodine, with the proper quantity of phosphorus and water, will be found quite sufficient, using a retort capable of containing about five or six ounces of water. Constant attention must be paid to this operation while it is going on.

647. A number of complicated changes take place during the preparation of this gas, from the reaction of the different

substances mixed together and part of the newly formed products. Small cubical crystals may frequently be seen in the neck of the flask or retort employed ; they consist of hydriodic acid and phosphureted hydrogen, and are rapidly decomposed by water with effervescence, this fluid combining with the hydriodic acid. The hydriodic acid gas is produced by the iodine combining with the hydrogen of a portion of water which is decomposed, the oxygen uniting with the phosphorus.

648. Other processes for the preparation of hydriodic acid gas have been recommended, but there is none by which the beginner can prepare a small quantity more easily than that which has been described. There are several circumstances with respect to the phosphureted hydrogen, and the other products that are formed at different periods of the process, according to the temperature applied, and the proportion of water employed, which require further investigation.

649. M. F. D'Arcet has proposed to prepare hydriodic acid gas in a very pure form, by heating a solution of hypophosphorous acid, till it begins to give off phosphureted hydrogen by decomposing water, after which it is to be cooled, and mixed with an equal weight of iodine. On subjecting the mixture to a gentle heat, the water affords hydrogen to the iodine, producing hydriodic acid gas, while its oxygen is transferred to the hypophosphorous acid.

650. When a considerable quantity of a solution of hydriodic acid in water is required, in which state it is usually kept as a test, the most convenient process consists in decomposing the iodide of starch, while suspended in water, by a stream of hydrosulphuric acid. (Journal of Science, New Series, No. viii.) Sixty grains of iodine are dissolved in three ounces of alcohol (kept cold), and an ounce of starch reduced to a very fine powder diffused in four ounces of water ; on adding this, drop by drop, to the first solution, and stirring it constantly at the same time, iodide of starch is formed ; the clear liquid is decanted after the iodide has subsided. A little water is then poured on it to separate any alcohol that may be still mixed with it, and after this has been removed, the iodide is diffused through an ounce of water, and a stream of hydrosulphuric acid, from 400 or 500 grains of the sulphuret of iron (315), passed through it till it becomes white. The liquid is then filtered to remove the

starch and sulphur that are disengaged, and boiled for a short time to expel any excess of hydrosulphuric acid. The iodide of starch may be put into a conical-shaped precipitate glass or jar when it is diffused through water, and the hydrosulphuric acid gas prepared as directed in paragraph 334.

651. In this process, the hydrogen of the hydrosulphuric acid combines with the iodine of the iodide of starch, and forms the hydriodic acid, which remains in solution ; while the sulphur and starch, being insoluble, are separated. The mixture passes through a variety of shades of colour from the deep blue of the iodide to a rich brownish-red, orange, and yellow colour, before it becomes ultimately white ; these changes succeed each other rapidly, and present a very beautiful appearance when the hydrosulphuric acid is quickly evolved. It has been affirmed that the hydriodic acid procured by this process is not pure, being contaminated with a small portion of starch, which is not easily separated. The process described in the succeeding paragraph affords it free from all impurity.

652. A solution of hydriodic acid in water may be obtained also by transmitting hydrosulphuric acid through water containing in suspension iodine reduced to a fine powder, the hydrogen combining with the iodine, and the sulphur being deposited. In the process described in 650, the iodine is obtained in a much more minute state of division than it can be procured in by trituration, and the hydrosulphuric acid acts more readily upon it in that state. In both cases, the liquid acid may be concentrated by evaporation till it is obtained of the specific gravity of 1.5, continuing the application of the heat for this purpose till its boiling point rises to 260° or 262°.

653. In this state, it is a transparent and colourless liquid, having very strong acid powers, and causing an effervescence with carbonates. It acquires a deep colour on exposure to air and light, from the decomposition of a minute portion of acid and the separation of iodine ; a portion of oxygen being absorbed and combining with part of its hydrogen.

654. Pour a small quantity of the acid into a dilute solution of litmus in water ; the colour immediately changes to a red.

655. Pour a few drops into six glasses, each containing an ounce or two of water. To the first, add a single drop of a solution of the bichloride of platinum ; the whole liquid immedi-

ately becomes of as deep a reddish-brown colour as the strong solution of the bichloride employed, and after some time a brownish-black precipitate is formed. The bichloride of platinum is the most delicate test of hydriodic acid. The compound formed is supposed to be the biniodide of platinum.

Symb. Cl² Pt & 2HI = 2HCl & I²Pt
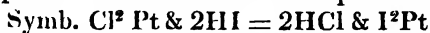
Into the other glasses pour a few drops of the following liquids :—

(2.) A solution of the bichloride of mercury ; it gives a precipitate of the biniodide of mercury, which appears yellow at first, but soon becomes of a brick-red colour. In this and the preceding case, the chlorine which leaves the metal in solution combines with the hydrogen of the hydriodic acid, producing hydrochloric acid.

(3.) A solution of the nitrate of silver ; a greenish-yellow precipitate of iodide of silver immediately appears.

(4.) A solution of the acetate of lead gives a brilliant yellow precipitate, consisting of the iodide of lead. All these precipitates are compounds of the iodine of the acid with the metal of the solution employed ; the acid originally in combination with the metallic oxide in the two last cases, is left in solution, water being formed at the same time, by the combination of the hydrogen of the hydriodic acid with the oxygen of the oxide.

(5.) Strong nitric or sulphuric acid decomposes it. The action in both cases depends upon the attraction exerted between the hydrogen of the hydriodic acid, and the oxygen of the other acids.

(6.) Chlorine water produces the same effect, the hydrogen being withdrawn, and the iodine set at liberty ; a solution of starch may be added afterwards to produce the characteristic blue precipitate.

656. With the hydriodic acid gas collected by displacement, several experiments may be performed. If any have been collected over mercury, it should be used as soon as it is prepared. One jar may be left over the mercury to shew its decomposition by this metal, the iodine combining with the mercury, while the hydrogen is left. It has been stated that when hydriodic acid gas is procured perfectly pure, mercury does not decompose it.

657. Remove a tube filled with the gas in the manner directed

in par. 266, and take the finger off the mouth under water ; the gas is absorbed as rapidly as hydrochloric acid gas, if it be not mixed with air.

658. Introduce a small quantity of water into a jar full of the gas over mercury (par 267) to shew the large quantity which it can absorb.

659. Fill a small jar half full of hydriodic acid gas at the mercurial trough, invert it with a tray, keeping the mouth of the jar upwards, and bring cautiously in contact with it the extremity of a narrow tube, or the beak of a small retort, from which chlorine is slowly escaping. About 50 or 60 grains of the binoxide of manganese may be employed with a proper proportion of hydrochloric acid, and a retort capable of holding one or two ounce measures. The chlorine combines immediately with the hydrogen of the hydriodic acid, forming hydrochloric acid gas : purple-coloured vapours of iodine appear, which speedily condense : and if much chlorine be brought at once in contact with the acid gas, an explosion attends the reaction, and a flash of light is at the same time perceived. The chlorine gas should be allowed to come for some time before it is applied to the hydriodic acid gas, that all the air may be expelled. About 3 or 4 cubic inches of hydriodic acid gas are quite sufficient for this experiment. The operator should place the vessel from which the chlorine is escaping on a retort-stand, and in such a situation that any excess of gas may be carried away by a current of air without annoying him.

660. Invert a jar full of hydriodic acid gas with an earthen tray, and pour into it a little of the strong fuming acid composed of nitric and nitrous acids. The hydrogen of the hydriodic acid immediately combines with the oxygen of the nitric acid, and iodine is set at liberty ; the mixture often inflames, even when the experiment has been made with no more than two or three cubic inches of the gas.

SECT. IV.—TERIODIDE OF NITROGEN, CHLORIODIC ACID, &C.

661. TERIODIDE OF NITROGEN is prepared by triturating iodine with common liquid ammonia, allowing the mixture to remain for 24 hours. Ammonia is composed of hydrogen and

nitrogen. Part of the iodine combines with the nitrogen, forming the teriodide, which assumes the form of a black powder, and another portion, uniting with the hydrogen is converted into hydriodic acid, which remains in combination with the water of the ammonia. It may be prepared in a small evaporating dish, covering it with a small plate or with another evaporating dish, and detonated in the same vessel, after pouring off the solution of hydriodic acid. A few grains of iodine and a drachm or two of ammonia will afford a sufficient quantity to shew its detonating properties.

662. Another mode of preparing this substance consists in agitating a saturated alcoholic solution of iodine with aqueous ammonia, when it is precipitated as a dark coloured powder, which may be covered with pure ammonia before it is used.

663. The teriodide detonates by slight pressure, or on exposing it to a moderate heat over a chauffer, its elements being separated from each other.

664. The action that takes place between iodine and phosphorus has been already described (631, 646). The PERIODIDE OF PHOSPHORUS consists of two eqs. of phosphorus and five of iodine. If it be required in a pure form, the iodine and phosphorus should be mingled in a deep glass-tube, twelve or fifteen inches long, after displacing the air by carbonic acid gas. Heat is then cautiously applied, after the materials have been mixed for some time. This compound must be carefully excluded from the air, as it produces quickly hydriodic and phosphoric acids, when the moisture of the air comes in contact with it.

665. Two other compounds of iodine and phosphorus have been prepared by the action of phosphorus with smaller quantities of iodine.

666. IODIDE OF SULPHUR is prepared by mixing iodine and sulphur, and exposing them to a gentle heat.

667. CHLORIODIC ACID or CHLORIDE OF IODINE is the name given to a compound of chlorine and iodine discovered by Sir H. Davy. It is prepared by admitting chlorine into an exhausted flask containing a fixed quantity of iodine.

668. Compounds of iodine and carbon have been formed by the reaction of solutions of potassa and iodine in alcohol, the carbon arising from the decomposition of the alcohol.

CHAPTER XI.—BROMINE.

Symb. Br.   *Eq. by W.* 78.4 ; *Sp. gr. of liquid Bromine*, 3.

669. BROMINE was discovered only a few years ago by Mr Balard. It is obtained by passing a stream of chlorine through bittern (the liquid that remains after boiling down sea-water to prepare common salt), and exposing it afterwards to heat in a retort, when bromine is separated in vapour, and may be condensed in a receiver. A few ounces of bittern are sufficient to shew this process for the preparation of bromine, though little more than a grain or two is obtained. In preparing the liquid, the chlorine must be transmitted through the bittern till the orange colour which it acquires ceases to become deeper. The chlorine which can be procured from 200 to 300 grains of the binoxide of manganese will be quite sufficient for passing through five or six ounces of bittern.

670. Bittern consists principally of sulphates and hydrochlorates of soda and magnesia, with a small quantity of the hydrobromate of magnesia, a compound of hydrobromic acid and magnesia. The hydrobromic acid is composed of hydrogen and bromine, and when the chlorine is transmitted through the bittern, it combines with the hydrogen and disengages the bromine, which imparts a yellow colour to the liquid. The vapour of the bromine has a deep reddish-brown colour, bearing a great resemblance to nitrous acid vapour, and condenses into a very dark coloured liquid.

671. If sulphuric ether be shaken with the bittern after the chlorine has been passed through it, the ether dissolves the bromine ; and when it is left at rest, the solution of bromine in ether collects at the top, having a very rich hyacinthine colour. On digesting it with a strong solution of potassa, two new salts are formed, the bromate and hydrobromate of potassa ; the latter is obtained in cubical crystals by evaporation, and on mixing it with binoxide of manganese and sulphuric acid in a glass-retort, the bromine is disengaged by the application of heat. For this process, at least two or three pounds of bittern should be employed.

672. In the second process, the bromate and hydrobromate of potassa are formed by one portion of the bromine combining with the oxygen, and another with the hydrogen of a portion of water which is decomposed. When the hydrobromate is afterwards mixed with sulphuric acid and binoxide of manganese, sulphates of potassa and manganese are formed, oxygen gas being disengaged, which takes hydrogen from the hydrobromic acid eliminated at the same time, while the bromine which is set at liberty is collected in the receiver.

673. Many other processes have been proposed for the preparation of bromine, analogous to those adopted for the separation of chlorine and iodine from their compounds.

674. Bromine is the only elementary substance that is liquid at natural temperatures, with the exception of mercury. Its present appellation is derived from its disagreeable odour. (βρωμος, *fœtor*.) In all its chemical relations it bears a great resemblance to chlorine and iodine, and its compounds are analogous to those which they form with the same bases; they may be prepared in the same way. For a more particular account of its properties, I must refer to the different scientific journals.

CHAP. XII.—FLUORINE.

Symb. F. *Eq. by W.* 18.7.

675. The existence of a peculiar elementary substance in the mineral commonly known by the name of Derbyshire spar is admitted by all chemists, and of late it has been prepared in an uncombined form, but not in such a state of purity as to admit of its properties being accurately determined. It was separated from its combinations by different processes, one of the most successful of which consisted in heating fluoride of calcium (fluor-spar) and binoxide of manganese with aqueous sulphuric acid. The aqueous sulphuric acid and the binoxide produce sulphate of manganese and oxygen, (see par. 27, page 11); with the fluor spar the sulphuric acid forms sulphate of lime and hydrofluoric acid, in the manner explained in the following section. The liberated oxygen is supposed at the same time to

attract hydrogen from the hydrofluoric acid, the fluorine being thus disengaged.

676. Fluorine is a gas, of a yellowish colour, with an odour similar to chlorine. It destroys vegetable and animal colouring matters, and is similar in its general chemical relations to chlorine, iodine, and bromine. In the last volumes of the Philosophical Magazine, the details of the more recent experiments upon fluorine are given.

SECT. I.—HYDROFLUORIC ACID.   (FLUORIC ACID.)

Symb. HF. *Eq. by W.* 19.7 (H. 1 + 18.7 F.). *Colourless and transparent ; emits copious dense white fumes on exposure to the air. Sp. gr.* 1.06.

677. To prepare hydrofluoric acid, fluor-spar (Derbyshire spar) is reduced to a very fine powder, and put into a leaden

Fig. 161.
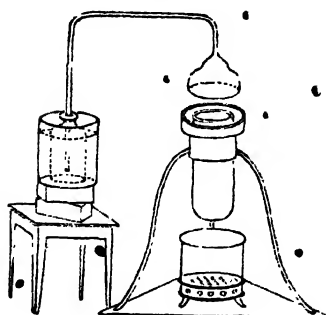
retort into which its own weight of sulphuric acid has been previously poured. The materials are mixed together with an iron rod, and on applying a moderate heat by a chauffer, hydrofluoric acid is disengaged ; a receiver of lead must be used to condense it. Instead of a leaden retort of the usual shape, an apparatus similar to that represented in the annexed figure will be found more convenient.

678. It is composed of a deep leaden cup, with a rim of lead soldered round the top, a small space being left between it and the upper part of the cup for fixing the head of the apparatus, when the materials have been put in. The easiest method of proceeding is to fill this intervening space with plaster-of-Paris, and put in the cover before it begins to set, taking care to have the tube and the bottle receiver, which are used along with it, properly adjusted at the same time, that it may not be necessary to shift it afterwards. The receiver is placed in a jar or basin, and surrounded with ice or very cold water. The heat ought

to be cautiously applied; a very small chauffer is all that is re-
quired; the bottom of the leaden cup is melted by applying too
great a heat; and the student ought to examine it occasionally
with an iron rod, and withdraw the chauffer for a little if he
should find it beginning to turn soft, or yield much more readily
than usual to the iron.

The body of the retort in the apparatus which I generally
use is rather more than two inches in diameter, and seven and
a half inches deep; it is supported by an iron ring resting on
three iron rods, which are fastened together at the bottom by
a plate of sheet iron, on which the chauffer is placed. Two,
three, or four ounces of fluor-spar may be used in it at a time,
or even more, if it be required.

679. Till lately, it was considered by many that fluor-spar is
a compound of dry hydrofluoric acid and lime, and, according to
this view, the dry sulphuric acid in the liquid acid employed
combines with the lime, and the hydrofluoric acid, uniting with
the water previously in combination with the sulphuric acid,
forms the vapour that condenses in the receiver. The more
common opinion, however, is, that fluor-spar is composed of
fluorine and calcium, (the metallic base of lime); and that the
water of the sulphuric acid is decomposed, the oxygen combining
with the calcium and forming lime, which remains in combina-
tion with the sulphuric acid in the leaden cup, while the hydro-
fluoric acid is formed by the fluorine combining with the hy-
drogen.

680. The greatest caution must be taken while experimenting
with this substance, as its vapours are highly irritating, and it
acts more violently on animal substances than any of the other
acids. A single drop falling on the skin instantly destroys the
part with which it comes in contact, producing a deep ulceration,
which is not easily cured, and accompanied in some cases with a
state of febrile irritation which has been known to continue for
months.

681. Hydrofluoric acid has all the properties of a very power-
ful acid, and is particularly distinguished by its action on silica,
combining with it, and forming a gaseous compound, which has
been termed fluosilicic acid. Hence, it cannot be either prepared
or preserved in glass vessels; silver and platinum vessels are

preferred ; but those made of lead, being much cheaper, are
generally employed.

682. From this property of combining with silica, it is used
for etching on glass, and it may be employed in the gaseous
state, or the strong acid diluted with four or five parts of water
may be taken.   The surface of the glass is coated in the first
place with bees' wax, which is not acted upon by this acid, and
figures are then traced upon it with a sharp-pointed instrument,
the wax being removed at the parts desired to be eroded. When
exposed to the vapour of the acid as it is disengaged from the
retort, the glass is immediately corroded where the wax has
been removed, the hydrofluoric acid combining with the silica
and forming fluosilicic acid.

683. On the small scale, the experiment may be performed
by mixing one, two, or three hundred grains of fluor-spar with
their own weight of sulphuric acid in a small iron cup.   The
cup is held over the fire till the hydrofluoric acid vapours begin
to be disengaged, and then the glass is placed over it, covering
the whole with a wooden or pasteboard box, to prevent the
vapours from escaping.   A little sand poured round the box,
where it rests on a table or on the ground, prevents in a great
measure the vapour from annoying the operator, especially if
moistened afterwards ; but all the materials and apparatus used
should be placed at a ventilator wherever this is practicable.

684. When the diluted liquid acid is used, it is poured on the
coated glass after figures have been traced on it, a small edging
of wax having been raised all round the glass to prevent it from
running off.   The vapour renders the glass rough and less
transparent than before ; but the transparency is not diminished
when the liquid acid is used.   By allowing it to remain on for
a longer or shorter period, the lines may be made more or less
deep.

685. The great objection to the use of hydrofluoric acid in
engraving or etching on glass is the inequality of its action, the
surface of the glass being unequally penetrated.

Sect. II.—Fluoboric Acid. (Terfluoride of Boron.)

686. This compound is obtained by exposing boracic acid and fluor-spar in a tube to a red heat. It may also be procured by mixing intimately one part of fused boracic acid with twice its weight of fluor-spar (having previously reduced them both to a fine powder), and twelve parts of sulphuric acid, in a glass-retort, heating the mixture by a lamp or chauffer. Half an ounce or an ounce of the fused boracic acid, with the corresponding proportions of fluor-spar and acid, affords a considerable quantity of the compound. Care must be taken to employ strong sulphuric acid in this experiment, otherwise the vapour that is disengaged does not form dense white fumes on exposure to the air. The common crystallized boracic acid cannot be substituted for that which has been fused, from the quantity of water which it contains.

687. Though generally considered at one time as a compound of hydrofluoric and boracic acids, it has of late years been more commonly regarded as a compound of fluorine and boron. According to this view, when prepared by boracic acid and fluor-spar, one eq. of boracic acid is entirely decomposed, communicating three eqs. of oxygen to three of calcium, and producing three of lime : these combine probably with three of undecomposed boracic acid, producing three of borate of lime. But the boron of the decomposed boracic acid, and the three eqs. of fluorine disengaged from the calcium, combine and produce fluoboric acid, which may accordingly be more specifically termed Terfluoride of Boron.

Symb. 4B & 3FCa = 3 (3B ·Ca) & F³B.

688. In the second process, sulphate of lime being formed and hydrofluoric acid disengaged by the reaction of fluor-spar and aqueous sulphuric acid, three eqs. of hydrofluoric acid and one of boracic acid produce three of water and one of the terfluoride of boron.

Symb. 3HF & ³B = 3·H & F³B.

689. Fluoboric acid exists in the gaseous state, and is largely absorbed by water, which condenses 700 times its volume of this gas, and acquires a specific gravity of 1.77. So great is its

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affinity for water. that it abstracts it from all gases containing any ; it thus forms very dense white fumes when allowed to mix with atmospheric air.

Sect. III.—Fluosilicic Gas.

Sp. gr. 3.611.   *Weight of* 100 *cubic inches* 110.13 *grains.*

690. This compound has been frequently alluded to in this chapter, and is procured by the action of silica and hydrofluoric acid.   It is a permanent gas at natural temperatures and under the usual pressure.

691. It is usually obtained by mixing intimately and heating one part of pounded glass with an equal weight of fluor-spar and two parts of sulphuric acid, the hydrofluoric acid disengaged by the action of the sulphuric acid on the fluor-spar reacting with the silica of the glass, and forming the fluosilicic gas.   The mixture may be heated by a small lamp or chauffer in a common glass-retort.   After a retort has been used three or four times, it is in general so much corroded by the action of part of the hydrofluoric acid, which takes silica from the glass of the retort. that it is apt to give way should it again be employed for the same operation.

692. It must be collected in jars over mercury, as it is decomposed by water.   By the action of the latter fluid about a third part of the silica is deposited, while the whole of the hydrofluoric acid and the remaining two-thirds of the silica are dissolved.   Water can condense in this manner 365 times its volume of fluosilicic acid gas.—(Dr J. Davy.)

693. A singular appearance is presented when the beak of a retort, from which fluosilicic gas is escaping, is introduced into a basin or pneumatic trough filled with water.   Each globule of the gas, the moment it comes in contact with the water, assumes the appearance of a vesicle, or thin membranous bag filled with air, rising through the fluid, and floating afterwards on its surface, quite distinct, for some time at least, from the remainder of the gas.   This arises from a coating of silica being deposited on the external surface of the globule, which protects the interior portions from the further action of the water.   Small tubes

may also be seen at the beak of the retort, produced by the deposition of silica from each bubble of gas as it escapes. These are sometimes continued to the surface of the water, but more frequently give way from time to time, from the impulse of a fresh portion of gas when they have become closed by an accumulation of silica.

694. Fluosilicic acid gas is extremely pungent and irritating. It does not corrode dry glass vessels, cannot support combustion, and forms white fumes with air containing watery vapour.

695. According to the most recent investigations, this substance has been termed terfluoride of silicum, being regarded as a compound of three eqs. of fluorine and one of silica. It is still, however, frequently referred to as a compound of hydrofluoric acid and silica.

CLASS II.

METALS, AND THEIR COMBINATIONS WITH NON-METALLIC SUBSTANCES AND WITH ONE ANOTHER.

ORDER I.—KALIGENOUS METALS.

CHAP. I.—POTASSIUM (or KALIUM.)

Symb. K. *Eq. by W.* 39.2 ; *sp. gr.* 0.865. *At* 32 . *it is hard and brittle, becomes soft and malleable at* 50°, *quite fluid at* 150°, *resembling mercury, and is volatilized below a red heat.*

696. POTASSIUM was discovered by Sir H. Davy, who obtained it by exposing the hydrate of potassa to the action of galvanism between two discs of platinum. Oxygen appears at the positive surface, and minute metallic globules of potassium at the negative, arising from the decomposition of the potassa, which is composed of oxygen and potassium. The potassa is not acted upon when perfectly dry, being a very imperfect conductor of the galvanic fluid while in this condition ; but it soon attracts a little moisture from the air, and is then decomposed. The water is decomposed at the same time, the oxygen being disengaged at the positive pole along with the oxygen of the potassa, and the hydrogen at the negative pole along with the potassium. A galvanic battery of 200 pairs of plates is quite sufficient to

shew these globules, but only a very minute portion of potassium can be procured in this manner.

697. Gay-Lussac and Thenard prepared it by fusing the hydrate of potassa, and causing it to flow over iron-turnings heated to whiteness in a gun-barrel. The oxygen of the potassa combines with the iron, and the potassium is at the same time volatilized, and may be condensed in a receiver connected with the gun-barrel.

·698. The process by which it is procured most easily is by distillation from a mixture of potassa or carbonate of potassa and charcoal.* This process was pointed out by Curaudau, and afterwards improved by Brunner and Wohler.

699. The mixture of charcoal and potassa is prepared most easily by exposing six or seven pounds of cream of tartar (crude tartar may be used) to a red heat, in large earthen or iron crucibles, till no more gas is disengaged. The gases that are disengaged arise from the complete decomposition of the tartaric acid, its oxygen and hydrogen abstracting part of its carbon, and coming away in the form of carbonic acid, carbonic oxide, and inflammable compounds of carbon and hydrogen. Part of the carbonic acid remains in combination with the potassa, forming carbonate of potassa, with which the remainder of the carbon of the tartaric acid is mixed. The residuum is to be reduced to powder in a mortar whenever it has become cold, and transferred immediately to the apparatus, that it may not attract water from the air.

700. Brunner states that when the tartar is mixed with $\frac{1}{12}$th of its weight of charcoal, a larger quantity of potassium is obtained. This additional quantity of charcoal is useful also in preventing the fusion of the carbonate of potassa at the high temperature to which it is afterwards exposed.

701. The mixture may be formed in the iron bottle in which the potassium is to be prepared, by heating it slowly to dull redness, till a blue flame appears.

702. I have frequently used an iron-pot (made of the best malleable iron), of the form represented in the following figure, about 12 inches long and 5 or 6 in diameter ; the iron should be

* Quarterly Journal of Science, vols. xv. and xxii. ; or Bib. Univ. xxi. and Annales des Mines, xii.

Fig. 162.
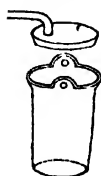
at least ⅜ths of an inch thick. The top is turned a little outwards, and a lid of the same metal and about the same thickness fitted accurately to it. The lid is secured in its place by an iron-rod, which is passed through two holes in the upper part of the opposite sides of the pot, where they are made to project for this purpose. An opening at one side of the lid admits a wide bent gun-barrel, intended to convey the potassium to a receiver.

703. The iron-pot should be luted before it is used, as it is apt to be softened, or at least corroded by the action of the air at a high temperature, when not protected in this manner. The best method is, in the first place, to bind the iron vessel round on every side with iron-wire, and cover it afterwards, to the depth of a quarter of an inch, with a stiff lute, made of Stourbridge clay*, with about a fifteenth part of iron-filings and charcoal; using no more water than is necessary to allow it to be easily worked, and mixing all the materials with a little thread cut into small pieces not more than an inch long, before adding the water. This is to be bound round again with iron-wire, and the whole then rubbed over with an additional quantity of lute.

704. The lower part of the iron-pot is easily covered with wire by providing a number of pieces a little longer than is necessary to go round both sides and the bottom of the iron-pot, bending them in the form of the letter U, and putting a thick piece of the lute on the bottom of the iron-pot, that they may be kept in their place till they have been fixed by the wire which is then wound round its sides. The mouth of the pot must be turned downwards all this time. When it has been inverted, and the materials put in, the finger is drawn round the edge of the lid with a little common clay, which prevents the lid adhering to the body of the iron vessel when it is at a high temperature. The lid is fixed in its place by the iron-rod, which is passed above it through the rings that project from the top of the iron-pot; a small piece of scrap-iron, such as the end of a broken chisel, is hammered in between the rod and the lid, to make it fit closely.

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* The common fire-clay found in the vicinity of Edinburgh does very well.

705. The bent gun-barrel, luted in the same manner as the iron-pot where it is to be exposed to the fire, is then introduced, and the ends of the iron-wire, still projecting over the top of the pot, are turned in over the lid and properly luted, taking care to protect the whole of the apparatus. If the furnace do not admit of the tube and the rest of the apparatus being put in together, it will be necessary to place the iron vessel in the furnace before the tube has been put in, and to finish the luting there. I have never seen this lute fail when properly put on, though the apparatus may have been used immediately afterwards : it is better, however, to allow it previously to dry a day or two before the fire, filling up any cracks that may be observed then with a fresh quantity of lute.

706. The iron-retort is placed above a piece of fire-brick resting on the branders of the furnace, and fixed to it with some fire-clay. The body of the furnace I use for an apparatus of the size described, is about 18 inches long, 15 broad, and 18 deep : the walls may be from 5 to 10 inches thick, and the flue rising from it 6 inches square (internal diameter), and carried up about fifteen feet ; in convenient situations it may be connected with a common flue. See the adjoining figure (163). The upper part of the furnace is covered by a flat cast-iron plate about ⅜ths of an inch thick, and having an opening in the centre through which fuel is introduced. A moveable cover of the same metal is fitted to the opening, and secured by an iron-bolt passing through a hole bored in it and in the plate ; this allows us to see very conveniently the state of the apparatus within the furnace. An opening is made at one side on a level with the branders, to allow the fire to be withdrawn whenever it may be necessary : it is constructed in such a manner that it may be easily closed up with a brick and a little mortar, which may be removed again with the same facility. A door is also
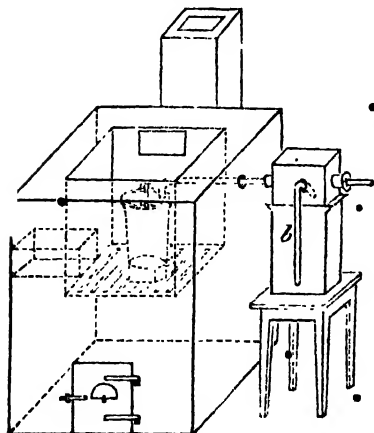
Fig. 163.

placed below to regulate the admission of the air, and a damper
in the vent to diminish the draught if this should be necessary.
The aperture in the side of the furnace for the gun-barrel must
not be forgotten.

707. After every thing has been properly adjusted, the fire
may be put on. A little water comes away when the apparatus
becomes red-hot ; soon after, carbonic oxide gas is evolved ; and
when it is at a white heat, a very dense vapour is disengaged,
which burns with a rich purplish flame. The receiver intended
to condense the potassium may then be fixed to the extremity
of the gun-barrel without the furnace, wrapping round the
joining pieces of cloth besmeared with some resinous cement.

708. The receiver recommended by Berzelius, which should
be kept cold by ice, is about a foot high, six inches long, one and
a half broad, made of copper or sheet iron, and composed of two
separate pieces, which are represented in Figures 164 and 165.
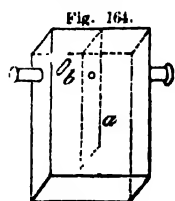
Fig. 164.

The first (Fig. 164) is open at the bottom and
close at the top, divided in the middle by a
partition (*a*) with a small hole in it, and pro-
vided with three openings,—one for connecting
it with the gun-barrel ; another (usually closed
by a plug) immediately opposite this for the
introduction of an iron rod or blade, to clear
the gun-barrel when it begins to be closed up by a black matter
collecting in it ; and another for carrying off the gas that is
disengaged, by a glass-tube (*b*), which allows us to judge how
the process is going on. The extremity of this tube dips into
naphtha.

709. The other piece (Fig. 165) is filled half full of naphtha,

Fig. 165.

and made of such a size that the upper one shall
fit accurately to it, and not pass into it without
some degree of friction. The receiver must be kept
quite cold by ice or very cold water ; the most of
the potassium is deposited before the gas that
comes along with it escapes by the glass-tube.
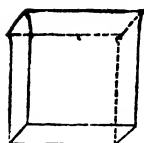
710. In Wohler's process, the iron-pot is placed horizontally.
In the upright position, the tube is not so apt to be filled up
with the carbonaceous and other matters carried over during
the distillation. In no case have I found any obstruction to

take place in the bent part of the tube, when placed so as to be within the furnace.

711. A plain wrought-iron bottle may be used instead of the preceding apparatus ; and to those who may not be much accustomed to chemical experiments, it will be more convenient to proceed in the manner illustrated by the accompanying figure, 166.

712. Take a stout iron-bottle such as is used for holding mercury, and lute it in the manner described (703). Introduce the cream of tartar and charcoal, intimately mingled, and give it a dull red heat till the flame loses the brilliant yellow tint that at first appears. Examine the luting ; fill up the crevices with more lute ; attach the tube, having luted it in the same manner as the iron-bottle where it is exposed to the fire, and then proceed as in paragraph 706, &c.

Fig. 166.
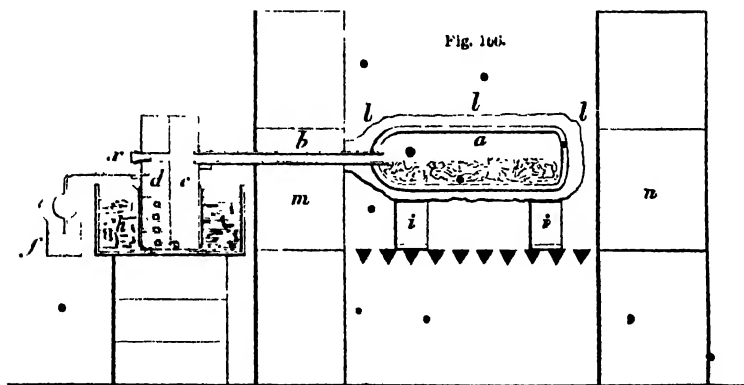
In the above figure, *a* represents the materials which afford the potassium, *b* the connecting tube, *c* and *d* the position of the naphtha in the receiver, when divided unequally by the gas loaded with potassium pressing the larger portion to *d*.　*h* is the freezing mixture surrounding the receiver, and *e* the tube by which the gas escapes after the potassium has condensed in the receiver ; *x* the aperture in the receiver by which the tube *b* is cleared : *m* and *n* are two parts of the wall of the furnace, which are closed only in a temporary manner, one (*m*) being required for the adjustment of the connecting tube, and (*n*) the

other being thrown open for the rapid removal of the fuel when the heat is withdrawn.

713. The figure below (167) represents the apparatus with the iron-blade introduced into the connecting tube, so as to clear it when it becomes obstructed with potassium. It must be very stout, and should be turned within the tube, steadily and cautiously, the hand being defended by a broad flat iron shield. It is represented in Figure 168.

714. A straight iron-rod is used instead of a blade when the obstruction is great, and a pick, Fig. 169, may also be used with advantage. The fire should at once be withdrawn when the obstruction in the tube cannot be overcome.

Fig. 168.

Fig. 169.

Fig. 167.
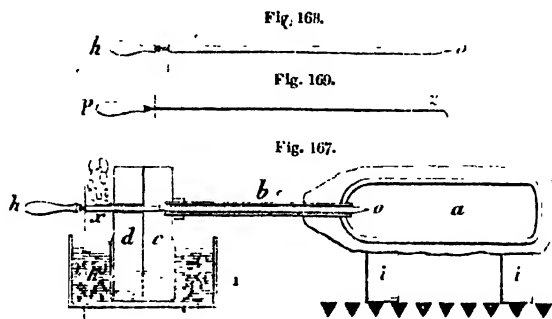
715. When the gas begins to be disengaged slowly, this arises in general from the tube being so obstructed as to prevent it from passing out readily; the plug is then taken out, and the obstructing matter removed as completely as possible, by turning round the flattened iron blade within the tube: but if the gas does not appear then to increase in quantity, it will be better to withdraw the fire and allow the apparatus to cool. Too much caution cannot be taken in endeavouring to clear the tube either during the distillation or after the apparatus has been allowed to cool, for the tube being frequently obstructed while the materials are at a high temperature and still producing gas, it is obvious that a large quantity must be accumulated in a short time, and the moment the impediment to its free passage is removed, it often expands with explosive violence, and gives rise occasionally to serious accidents.

716. On one occasion when the apparatus had not been touched till 36 hours after the fire had been withdrawn, on tap-

ping the gun-barrel to remove it more easily, a very violent explosion took place, partly owing to the sudden escape of gas condensed within it, and partly to the action of a peculiar detonating compound which is formed within the tube, small quantities of which were found in almost every part of the room, and exploded with very little friction.

717. The operator ought accordingly always to be protected in the most complete manner, and never be without a mask; processes like this also should be excluded from class-rooms, where there is not an experienced assistant to give them that constant and undivided attention which they require.

718. Occasionally, too, when the tube becomes completely obstructed, I have seen the vapours of potassium forced through between the lid and the top of the iron vessel, burning with a rich violet-coloured flame, easily distinguished by its beautiful colour from the flame produced by the combustion of the fuel. The fire must be withdrawn immediately whenever this appears.

719. Common carbonate of potassa mixed with charcoal, was frequently tried, after it had been fused to dry it as completely as possible, but the calcined cream of tartar mixed with carbon is preferred, as the potassa is obtained in this manner more intimately mixed with the carbon of the decomposed tartaric acid. When a mixture of charcoal and iron turnings was employed, a higher temperature appeared to be necessary to disengage the potassium, and a smaller product was obtained.

720. The potassium collects principally in the first division of the receiver, part of it is deposited in the second, and a small quantity is sometimes found in the jar of naphtha in which the extremity of the tube *e* is placed. It is never perfectly pure, being always mixed with a small portion of carbon ; I have often found the purest part of the potassium lining the gun-barrel before it has entered the receiver.

721. It is usually recommended to purify potassium by distillation in a common glass-retort, but, on trying this operation, it will be found that the temperature required for the volatilization of the potassium generally enables it to decompose the glass, which is often completely destroyed, when a considerable proportion of the potassium is lost. A green glass-retort is less apt to be destroyed, or foreign white glass-retorts may be used.

some of which contain no lead, and can bear as high a tempera-
ture as the green glass-retorts made in this country.   It will,
perhaps, be better always to distill from a small iron vessel or
tube retort heated by a chauffer. ·

722. In condensing potassium in the receiver, naphtha is the
liquid that must be employed, as potassium can decompose every
fluid which contains even a minute quantity of oxygen, combin-
ing with it and forming potassa.   The same fluid must also be
employed to preserve the potassium, that it may not be oxidated
by the air.   The naphtha used for this purpose should be se-
lected with great care, as it is often met with of inferior quality,
and so largely charged with moisture, or with oxygen, that the
potassium is quickly oxidated by it.

723. Should it be required merely to illustrate the principle
on which potassium is procured by distillation, a piece of gun-
barrel closed at one extremity, and about 14 inches long, may
be coated with fine clay and iron-wire in the manner described.
Then fill it to the depth of about 3 inches with the proper ma-
terials (see 699), and introduce the close and coated extremity
into a furnace, so that it shall lie horizontally in the same man-
ner as the tube represented in the chauffer, Fig. 108, page 115.
A common brick-furnace, or one of Black's furnaces, Fig. 11,
page 7, may be used for this purpose.   When the gun-barrel
is sufficiently heated, the potassium is disengaged along with
much inflammable gas, which burns with the characteristic co-
loured flame.

724. The leading character of potassium is the great affinity
which it has for oxygen.   Cut a small portion of potassium with
a pen-knife, so as to observe its brilliant metallic lustre, and
how speedily it attracts oxygen from the air, a white crust (po-
tassa) gathering immediately upon its surface.

725. Take a small piece of potassium, about a grain, remove
the naphtha adhering to it by blotting-paper, and place it with
a pair of pincers on a piece of red-hot iron.   It will immedi-
ately take fire, combining with the oxygen of the air, and being
converted into peroxide of potassium.

726. Put another piece into a brass or copper cup (Fig. 73,
page 50) already at a high temperature, and introduce it the
moment it is inflamed into a jar or bottle of oxygen gas, when
it will burn more brilliantly than before.   Throw a little water

on the orange-coloured matter that remains after either of these experiments ; part of its oxygen is disengaged with effervescence, and potassa remains in solution. On pouring the solution into a little of the infusion of red cabbage, it will immediately become green ; potassa turning the vegetable blues to a green.

727. Throw a few pieces of potassium into a basin full of water ; one portion of it immediately combines with the oxygen of part of the water which is decomposed, forming potassa, while the other, uniting with the hydrogen, forms a very inflammable gas,—potassureted hydrogen, which takes fire as it is disengaged, and is converted into potassa and water. The potassium rolls along the surface of the water till the whole of it is oxidated, burning with a rich rose-coloured flame, and producing a very beautiful appearance. In performing this experiment, the operator must stand at a little distance, as at the instant that the potassium ceases to burn on the surface of the water, sparks of caustic potassa are often thrown about, in consequence of the action of the water on the globule of melted potassa.

728. Put another piece of potassium on a mass of ice ; the same action takes place, and a similar light is produced. Great care must be taken in performing this experiment, as the potassium is apt to act violently upon the ice, and is sometimes thrown in fragments to a considerable distance.

729. Take a piece of potassium (about a grain), wrap it up in a small piece of paper, and 'introduce it quickly into a glass test-tube inverted under water and full of this fluid. It will immediately rise to the top, and the moment the water reaches it through the paper, part of it will be decomposed, the oxygen combining with the potassium, and forming potassa, while an equivalent portion of hydrogen gas is found in the tube, and may be inflamed by applying a 'lighted match in the usual way.

730. Take a small piece of potassium (about a quarter of a grain), and allow it to fall into a little sulphuric acid placed in a tumbler, or, what is better, in the bottom of a jar three or four inches in diameter and about ten or twelve deep. The potassium immediately attracts a portion of oxygen, and becomes potassa, with which the sulphuric acid immediately combines. Heat and light are at the same time produced. The

student must take care to avoid any sparks of sulphuric acid
that may be thrown out.

731. Put two grains of iodine into a common test-tube about
four or five inches long, throw a grain of potassium upon them,
and hold the sealed extremity of the tube for a second or two
in the flame of a spirit-lamp. The iodine and potassium im-
mediately combine, a brilliant light is at the same time per-
ceived, and the tube is broken. A glove should be put on
when performing this experiment, and the mouth of the tube
turned away from the operator.

732. Take another tube of the same size, and proceed in the
same manner with half a grain of sulphur and a grain of po-
tassium. Sulphuret of potassium is formed, heat and light are
evolved, and the tube is generally broken. In both cases, the
heat and light are produced independently of the action of the air.

733. Take three or four grains of potassium, put them into
a suspended metallic cup, Fig. 73. page 50, and after heating it
for a short time in the flame of a spirit-lamp, introduce it into
a vase or bottle containing about twelve or eighteen cubic
inches of hydrosulphuric acid gas. The potassium in this case
also is converted into a sulphuret, and the usual phenomena of
combustion are seen : the hydrogen gas is disengaged.

SECT I.—POTASSA OR POTASH.

Symb. OK^c *or* $\cdot K$. *Eq. by* W. 47.2 *(oxygen* $8 + 39.2$ *potassium).
Very soluble in water and in alcohol. The Hydrate (Symb.
$\cdot H \cdot K$) fuses before it is heated to redness.*

734. Very pure potassa is obtained when potassium is exposed
to the action of air or water, as in any of the preceding experi-
ments ; the expense of this process, however, must always pre-
clude its being adopted for ordinary purposes.

735. The common process for obtaining potassa consists in
first preparing a solution of it from the carbonate, and then
evaporating the solution to dryness to expel the water, in a silver
or iron basin carefully protected from the air, urging the heat
afterwards till the dry mass is fused and begins to flow like oil.

736. To prepare the solution of potassa, carbonate of potassa

may be dissolved in ten times its weight of water. The solution is then decanted, mixed with a quantity of newly slaked lime equal in weight to the carbonate employed, boiled for a few minutes, and then filtered to separate the solution of potassa that is procured from the carbonate of lime with which it is mixed.

737. According to Liebig, lime does not remove carbonic acid from the carbonate of potassa, unless it be dissolved in more than four parts of water.

738. On the small scale, the throat of the funnel is obstructed by a glass-stopper or a piece of quartz, covering it closely with a piece of linen to prevent any lime passing through with the clear solution. As potassa speedily attracts carbonic acid from the air, and becomes carbonated, the solution must be protected from the air as much as possible during the operation. The best method of effecting this is, by using a funnel with a narrow mouth, which may be easily closed by a cork or stopper, and putting a small tube through the throat of the funnel, placing pieces of quartz or broken glass round it, and covering it with linen, so that while the solution of potassa is dropping into the bottle below, air passes through the tube at the same time from the lower to the upper vessel, and supplies its place. Thus the potassa comes in contact with no more air than that in the apparatus. This ingenious method was proposed by Dr Duncan (Dispensatory), and is an excellent substitute for a more complicated apparatus. When a common funnel is employed, it should be covered with a plate or tin tray, and a towel thrown over the whole.
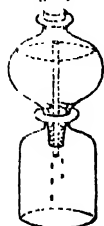
739. All the solution of potassa is not obtained in this manner, as a considerable portion of it adheres mechanically to the lime. To procure the remainder, a small quantity of water is poured carefully on the top of what is left in the funnel after it has ceased to drop ; the water presses upon the potassa still diffused through the mass, and causes it to pass slowly into the receiver below. This is continued till a quantity of liquid is obtained equal to five or six times the weight of the salt employed. It must be kept in glass-bottles with good stopples.

740. In this process, the lime, having a greater affinity for carbonic acid than potassa has, abstracts the carbonic acid, car-

bonate of lime being formed, which is insoluble and remains in
the funnel, while the potassa passes through in solution.   It is
impossible in this manner to remove the carbonic acid com-
pletely from the potassa ; it is sufficiently pure, however, for
many chemical purposes, when the precautions which have been
mentioned are carefully attended to.   (See par. 748.)

741. If the solution contain little carbonic acid, it gives a
very slight precipitate with lime water, and scarcely presents
any appearance of effervescence with sulphuric acid.   If it be
free from lime (which is occasionally present), it will not be
rendered turbid on blowing through it with a bent tube.

742. It is from this solution that solid potassa is usually
formed, evaporating it to dryness, and then fusing the mass that
remains with a heat gradually increased till it flows like oil,
when it may be poured into moulds or on a plate of iron.   It
should then be broken into pieces, and put into a bottle, to pre-
vent it attracting water or carbonic acid from the air.   In this
state it forms the *fused potassa,* or *common caustic* of the different
Colleges.

743. When prepared in a silver vessel, it is usually of a white
or greyish-white colour. and free from iron ; but when iron ves-
sels are used (which should be bright and clear), a portion of
oxide of iron is always mixed with it, giving it a brownish colour,
and separating from it when it is dissolved in water.   Hence
the origin of the brownish matter which is usually deposited on
dissolving caustic potassa in water.

744. Though it is generally termed potassa, or caustic pot-
ash, it is in reality a compound of dry potassa and water, one
equivalent of the alkali retaining in combination one equivalent
of water, which cannot be separated by exposing it even to a
temperature far above a red heat.   HYDRATE OF POTASSA is
therefore its proper chemical appellation.   It has been found
also that part of the potassa attracts an additional quantity of
oxygen during its fusion, and is converted into peroxide of po-
tassium ; but this is not of any consequence in experimenting,
as the excess of oxygen is again disengaged when it is dissolved
in water.

745. Perfectly pure and dry potassa is formed when potassium
is spread out into thin layers and exposed to the action of the

air. The hydrate is the compound used for almost all chemical purposes.

746. Expose some hydrate of potassa to the air ; it soon attracts moisture and becomes fluid, but after absorbing still more water, a dry pulverulent substance is formed, the TERHYDRATE of POTASSA ($3 \cdot H + \cdot K$).

747. Another compound, containing five eqs. of water and one of potassa, has been obtained by exposing a strong solution of potassa to intense cold.

748. It is obvious that the fused potassa prepared from the solution obtained by decomposing the carbonate, must always contain any carbonic acid that has not been withdrawn by the lime ; accordingly, when potassa is required perfectly pure, this must be separated. This is effected by digesting it in strong alcohol, which dissolves the potassa, but leaves any carbonate that may be mixed with it : the alcohol is afterwards separated by distillation.

749. Throw some pieces of common fused potassa into a little water ; they are speedily dissolved, and considerable heat is produced if the quantity of water be not great. The solution has a very acrid alkaline taste, even when largely diluted with water. It is turbid, from the separation of oxide of iron, and also effervesces slightly from the evolution of a little oxygen, which arises from the decomposition of peroxide of potassium mixed with the potassa.

750. Pour a little of the solution into a glass of water tinged with the blue infusion of cabbage : it immediately becomes of a fine green colour, which speedily passes to a yellowish-brown, as the caustic potassa, especially when the solution is strong, completely destroys the vegetable colouring matter.

751. Pour some of the solution of potassa into two glasses of water, one coloured by an infusion of turmeric, and the other by a solution of litmus. The turmeric immediately becomes brown, and the litmus remains unaltered. If the litmus, however, should previously have acquired a reddish tint, it will be rendered blue, the acid being neutralized by the potassa.

752. Fill a number of glasses nearly full of water, and drop into them small quantities of the solutions of a number of salts, as the hydrochlorate of lime, the sulphate of magnesia, the sulphate of iron, the sulphate of copper, and the acetate of lead.

P

Then drop into each a small quantity of the solution of potassa. It combines with the acid in combination with each salifiable base, all of which is separated, if a sufficient quantity of the alkali be employed ; for potassa, when in solution and at natural temperatures, has a much greater affinity for the sulphuric. hydrochloric, acetic, and most acids, than the other salifiable bases. It generally forms soluble salts with them, while the bases which it separates are either insoluble, or require a large quantity of water for their solution, and are thrown down in the form of precipitates.

753. The student should perform a number of similar experiments with the other alkalis, and those earths which are soluble in water, as he proceeds, till he becomes more familiar with the different substances with which they are incompatible, and their general chemical agency. Potassa neutralizes the acids, forming salts of various kinds, according to the nature of the acid ; it is incompatible in general with soluble salts of the earths and common metallic oxides, precipitating them from their solutions, and combining with the acids previously in combination with them ; it decomposes the chloride and bichloride of mercury (calomel, and corrosive sublimate), producing compounds which will be described under mercury, &c. Its solution in water can dissolve a number of metallic oxides. He need not attend, however, to the minutiæ of its action on different bodies, till he come to study the different substances themselves.

754. *Potassa with lime*, or the *milder caustic* of the Edinburgh and Dublin Colleges, is made by mixing the solution of potassa (prepared from the carbonate) with slaked lime in fine powder, till it becomes of a thick consistence. expelling about two-thirds of the water by evaporation.

755. Potassa is used in medicine as a caustic, and is occasionally administered internally in calculous diseases. For chemical purposes, it is extensively employed in the arts. It is the basis of common soft soap, forms glass with silica, and is used in preparing cloths for bleaching, dyeing, &c. It is an important analytical reagent.

756. The tests by which potassa is most easily distinguished from soda, the substance for which it is most likely to be mistaken, are the chloride of platinum, tartaric acid, perchloric acid, and carbazotic acid. The first gives a yellow-coloured

precipitate (chloride of potassium and platinum) with salts of potassa when they are sufficiently concentrated, but does not affect those of soda. Tartaric acid produces the sparingly soluble bitartrate of potassa. Perchloric and carbazotic acids also produce with potassa compounds which have little solubility.

757. The potash or potashes of commerce are obtained by digesting the ashes of burned wood in water, to extract the soluble matters which they contain, and boiling down the liquid afterwards to expel the water. They consist principally of the carbonate of potassa, with hydrate of potassa and small quantities of the sulphate and hydrochlorate of potassa, sulphuret of potassium, and earthy substances. When they are dissolved in water, the solution filtered and evaporated to dryness, and the residuum exposed to heat in a reverberatory furnace, stirring it constantly at the same time, it is more completely carbonated, and forms what is termed *Pearl Ash*, from its white colour. A portion of alkaline matter may be obtained in ·solution by pouring water on the ashes of a wood-fire, and filtering the liquid, which will then turn the infusion of red cabbage to a green colour.

SECT. II.—SALTS OF POTASSA ; SULPHURET, CHLORIDE, AND IODIDE OF POTASSIUM.

758. In describing the salts of the different alkalis, earths, &c., I shall at the same time consider the sulphurets, chlorides, and iodides of their respective bases, and other analogous compounds, when they are of sufficient interest.

759. NITRATE OF POTASSA, NITRE, or SALTPETRE, crystallizes in six-sided prisms. It is soluble in about 3 parts of water at 60°, and in less than its own weight of boiling water. It is volatile when boiled with water, but only very small portions escape at a time from its boiling solution.

760. Add nitric acid to a solution of potassa or of carbonate of potassa, till it is completely neutralized, and evaporate the solution that crystals of the nitrate may be formed as it cools.

761. Nitre is never prepared in this manner, however, for use in the arts, as it is an abundant product of nature, appearing in the form of an efflorescence on the surface of the earth, in tropical countries, as the East Indies. It is also

formed artificially in large quantities in *nitre beds*, by mixing lime and carbonate of lime with animal and vegetable substances, and exposing them to the air ; the nitrogen of the nitric acid which is formed being derived from the animal matter and the air, and the oxygen from the same sources. The lime unites with the acid as it is produced, and forms nitrate of lime, a salt which is easily dissolved by water. On adding carbonate of potassa, a double decomposition immediately takes place, nitrate of potassa remaining in solution, while carbonate of lime is precipitated.

762. Nitre is always contaminated with common salt (chloride of sodium), in the state in which it is usually met with in commerce : and *Rough Nitre*, that is, nitre in the state in which it is imported, is mixed with a large quantity of this substance. They are in a great measure separated from each other by solution in hot water and crystallization, but it is very difficult to remove every trace of common salt by this process. To illustrate the method of proceeding, dissolve 8 parts of common nitre in 12 parts of boiling water, heated in a glass-flask or earthen evaporating basin by a lamp or chauffer. Filter the solution, and then set it aside in a cool place to crystallize.

763. Let equal weights of the crystals procured in this manner and of common nitre be dissolved in equal weights of distilled water, and add to each an equal quantity (a few drops) of a solution of the nitrate of silver. A more copious precipitate appears in the solution of the common nitre, for it contains more common salt. The chlorine, one of the elements of this salt, whenever it meets with silver in solution, unites with it, forming a white precipitate.

764. By dissolving the crystals of nitre procured by the above process in another portion of distilled water, and crystallizing again, the crystals that are now deposited are still purer than those obtained at first ; and in this manner, by a few successive crystallizations, nitre may at last be procured almost entirely free from any trace of common salt.

765. In each of these cases, the liquid that remains above the crystals is an impure saturated solution of nitre, and on evaporation, it affords crystals of nitre, which contain more common salt than those at first employed.

766. The amount of common salt in nitre may be estimated

by dissolving 100 grains in two ounces of water, and adding nitrate of silver so long as any precipitate appears. This is to be washed, dried, heated, and weighed ; every 143.8 grains indicate 59 of common salt in the nitre.

767. Nitre is easily melted by exposure to heat, and when thrown into moulds in this state, so as to have the form of flat cakes or round balls, it forms what is sold under the name of SAL-PRUNELLE.

. 768. Though nitre contains no water of crystallization, a portion of the solution from which it crystallizes is generally retained between the layers of the crystals. Hence, in preparing gunpowder, and other substances where the nitre is required extremely dry, the nitre is fused previously, that any water may be expelled. If the nitre be incautiously heated too much, a portion of the acid is decomposed, and the nitre is also apt to become deliquescent. Nitre that has been too much heated gives ruddy fumes when moistened with water and then covered with aqueous sulphuric acid. If the nitre be pure and uninjured by the heat employed to melt it, the fumes evolved on the addition of the sulphuric acid are colourless (771).

769. Nitre parts easily with oxygen when heated, especially if mixed with metals or the simple inflammables. In the arts, it is used principally for the preparation of nitric acid and gunpowder, and a number of fulminating and deflagrating compounds.

770. Nitre is used for the preparation of oxygen, or for oxidating a number of substances, and occasionally for producing cold ; the temperature falls about 15 degrees, when nitre is dissolved in about five times its weight of water.

771. Take 200 grains of nitre, expose them to heat in a Hessian crucible, placed in a common fire, and pour half of the liquid mass on a dry iron plate as soon as it has been melted. Heat the remainder in the fire, and keep it in a state of gentle ebullition for 15 or 20 minutes, after which pour it out on the iron plate, taking care that it does not mix with the former portion. Then take a few fragments of each, put them into separate glasses, moisten them with a few drops of water, and pour a little strong sulphuric acid on them. This acid unites at once with part of the potassa in both cases. But nothing is disengaged from the nitre which has been merely melted, except a

little nitric acid vapour; while in the other instance, nitrous acid vapours immediately appear, much of the nitric acid having been decomposed, and nitrite or hyponitrite of potassa being left.

772. Mix intimately 300 grains of nitre, 60 of charcoal, and 40 of sulphur, previously reduced to a fine powder. These are the proportions of nitre, charcoal, and sulphur in some of the best kinds of shooting powder ; and though the mixture cannot be made to have the same appearance as ordinary gunpowder without appropriate machinery, it will be found to deflagrate somewhat in the same manner, on applying a light : but not with that quick and sharp detonation which is observed only in gunpowder that has been properly manufactured.

773. The port-fire used for firing artillery is made of three parts of nitre, two of sulphur, and one of gunpowder, well mixed and rammed in cases ; a small quantity of materials will be sufficient to shew the appearance which it presents on burning.

774. Signal lights are generally composed of nitre and sulphur, with a small quantity of some metallic sulphuret, as that of arsenic or antimony. Mix 600 grains of nitre with 200 of sulphur and 100 of the yellow sulphuret of arsenic ; put the mixture into a cone of paper, and touch it (out of doors or under a large chimney) with a red-hot iron ; it deflagrates rapidly with a brilliant white light.

775. Mix 100 or 200 grains of the sulphuret of antimony with the same proportions of nitre and sulphur, and inflame the mixture in the same manner. It deflagrates immediately, with a vivid light which has a bluish tinge.

776. Sulphate of Potassa crystallizes in six-sided prisms terminated by six-sided pyramids, which do not contain any water of crystallization, and are soluble in sixteen parts of cold and in five of boiling water.

777. This salt is easily obtained from the residuum of the distillation of nitric acid (189, &c.) ; dissolving it in water and adding carbonate of potassa till the excess of acid is completely neutralized. The solution is then evaporated till a pellicle appears on the surface, and small crystals of the sulphate are deposited on cooling. Carbonate of lime is occasionally employed, instead of carbonate of potassa, to remove the excess of acid, continuing to add it to the solution of the supersulphate as long

as any effervescence takes place. The following diagram shews the action that takes place, supposing all the potassa to be in the state of bisulphate, and carbonate of lime to be employed.

Fig. 171.

Before Decomposition.		After Decomposition.
127.4 Bisulphate of Potassa......	{ Potassa............47.2----------87.3 Sulphate of Potassa. { Sulphuric Acid 40.1------- { Sulphuric Acid 40.1	
50.62 Carbonate of Lime...... ..	{ Carbonic Acid..22.12............22.12 Carbonic Acid. { Lime..............28.5---------68.6 Sulphate of Lime.	

Symb. 2 S̈ + ˙K & :C ˙Ca = S̈ ˙K & S̈ ˙Ca & :C.
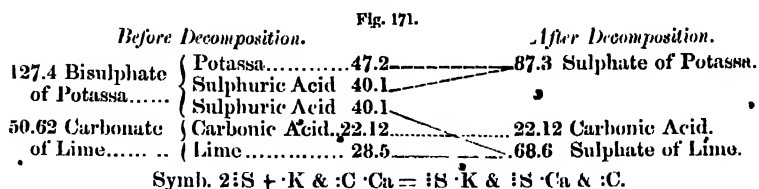
Most of the sulphate of lime remains undissolved, the carbonic acid is expelled with effervescence, and the neutral sulphate of potassa is obtained in solution. On the small scale, it will be much better to employ carbonate of potassa, as it saves the trouble of filtering the solution to separate it from the sulphate of lime, and no sulphate of lime is present to interfere with the crystallization.

778. BINAQUEOUS BISULPHATE OF POTASSA. If the bisulphate of potassa, such as remains after preparing nitric acid from nitre with two eqs. of sulphuric acid, be dissolved, and the solution set aside for crystallization, it is resolved into sulphate of potassa and super-salts. It has accordingly been recommended, when crystallized bisulphate of potassa is required, to boil two pounds of the above salt, with one of aqueous sulphuric acid, and four pints of water. The solution that remains, after crystallizing, is extremely acid.

779. The *Sulphas Potassæ cum Sulphure* of the Edinburgh College is prepared by throwing equal weights of nitre and sulphur into a red-hot crucible; the sulphur reacts on the oxygen of the nitre, and forms a compound, the precise composition of which is still undetermined; but it is very different from a mere mixture of sulphate of potassa and sulphur. It probably contains a little sulphate with hyposulphite and sulphite of potassa, and sulphuret of potassium.

780. A number of compounds of sulphur and potassium have been described, the most important of which is the SULPHURET OF POTASSIUM. It is usually prepared by decomposing the sulphate of potassa by charcoal : the sulphate is reduced to a very

fine powder, mixed with about a fourth part of charcoal also in
fine powder, and the mixture is then exposed to a strong heat
in a furnace. Carbonic oxide and carbonic acid gases are dis-
engaged, the oxygen both of the sulphuric acid and of the potassa
combining with the carbon, while the sulphur of the acid and
the potassium of the potassa remain in combination. Two or
three hundred grains of the sulphate, with the proper quantity
of charcoal, will be sufficient to shew the nature of the process.

The diagram below represents the theory of the decompo-
sition, supposing no carbonic acid to be formed, which is pro-
bably the case when a sufficient quantity of carbon is employed.
See Sulphuric Acid, par. 303, for Gay-Lussac's remarks on the
decomposition of sulphates.

Fig. 172

Before Decomposition.			After Decomposition.
24.48 Carbon...	Carbon,	6.12	14.12 Carbonic Oxide.
	Carbon,	6.12	14.12 Carbonic Oxide.
	Carbon,	6.12	14.12 Carbonic Oxide.
	Carbon,	6.12	14.12 Carbonic Oxide.
40.1 Sulphuric Acid	Oxygen,	8	
	Oxygen,	8	
	Oxygen,	8	
	Sulphur,	16.1	
47.2 Potassa...	Oxygen,	8	
	Potassium,	39.2	55.3 Sulphuret of Potassium.

Symb. 4 C & 3 S K = 4 C & SK
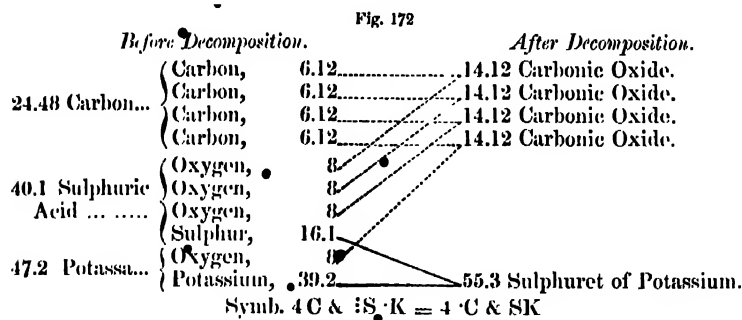
781. Sulphuret of potassium may be prepared also by heating
the carbonate of potassa with sulphur in a large crucible; the
heat ought to be applied cautiously, and continued till the mix-
ture is completely fused. One part of sulphur and four of car-
bonate of potassa are frequently used. It is in this manner that
the different Colleges prepare what they term *sulphuret of
potassa;* but it is in reality a mixture of sulphuret of potassium
and sulphate of potassa.

782. The next diagram illustrates the manner in which four
eqs. of sulphur and four of potassa produce three of sulphuret
of potassium and one of sulphate of potassa. The carbonic
acid, which is disengaged, is not represented.

Fig. 173.

```
Potassa....................47.2_ _____87.3 Sulphate of Potassa.
              ⎧ Sulphur,   16.1_
Sulphur,      ⎪ Sulphur,   16.1
4 eqs.,       ⎨ Sulphur,   16.1
              ⎩ Sulphur,   16.1
              ⎧ Oxygen,    8
              ⎪ Oxygen,    8
Potassa,      ⎨ Oxygen,    8
3 eqs.,       ⎪ Potassium, 39.2____     55.3 Sulphuret of Potassium.
              ⎪ Potassium, 39.2____     55.3 Sulphuret of Potassium.
              ⎩ Potassium, 39.2____     55.3 Sulphuret of Potassium.
```
Symb. 4 S & 4 ·K = ⦂S ·K̶ & 3 SK̶. .
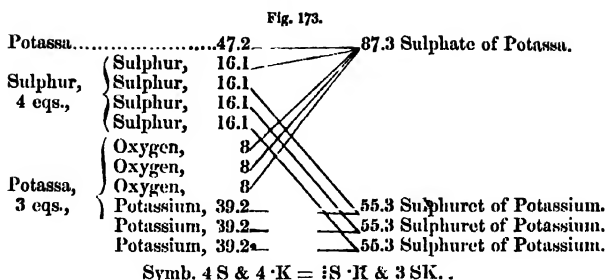
783. From its colour resembling that of the liver, it is often called *Hepar sulphuris*. If diluted sulphuric or hydrochloric acid be thrown on fragments of the sulphuret of potassium, hydrosulphuric acid gas is disengaged.

784. Digest in water the sulphuret obtained 'in the manner first described. A reaction immediately takes place between it and a portion of the water, and a solution of the HYDROSULPHATE OF POTASSA is obtained, the potassium taking the oxygen, and the sulphur the hydrogen, in the manner represented in the diagram.

Fig 174.

Before Decomposition.   *After Decomposition.*

```
9 Wate .....  ⎧ Hydrogen,  1_____17.1 Hydrosulphuric Acid.
              ⎩ Oxygen,    8
55.3 Sulphuret ⎧ Sulphur,  16.1
of Potassium.. ⎩ Potassium, 39.2____47.2 Potassa.
```
Symb. ·H & SK̶ = HS + ·K.
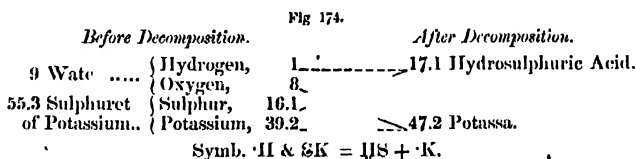
785. Boil 64 grains of sulphur with 114 grains of the hydrate of potassa in an ounce of water. The whole of the sulphur and potassa is dissolved, and a solution is obtained of a dark greenish colour. It contains the sulphureted hydrosulphate of potassa, and a portion of the sulphate, sulphite, or hyposulphite of potassa; these are formed by part of the sulphur combining with the hydrogen, and another part with the oxygen of a portion of water which is decomposed, the acids produced in this manner remaining in combination with the potassa.

786. An additional quantity of sulphur may be dissolved with the same quantities of water and alkali: the solutions have a deep amber colour when they have become clear, attract oxygen

from the air, and are decomposed by the acids, with disengagement of hydrosulphuric acid, and a copious precipitation of sulphur.

787. Sulphate of potassa may be decomposed by heating it with charcoal and carbonate of lime, a fused mass remaining, from which, by lixiviation, a solution is procured consisting principally of carbonate of potassa. The precise operation of the carbonate of lime is not well understood ; it assists in withdrawing the sulphuric acid from the potassa, and in communicating carbonic acid.

788. CARBONATE OF POTASSA is very deliquescent, and soluble in less than its weight of water. It is usually termed *Subcarbonate* of Potassa, as it possesses decided alkaline properties, the acid which it contains not neutralizing the alkali completely.

789. The PEARL ASH of commerce is an impure carbonate of potassa, containing siliceous matter, a little sulphate of potassa, a small quantity of other salts, and a portion of water, usually amounting to three eqs. in two of the carbonate. A solution sufficiently pure for ordinary experiments may be obtained by stirring it with one or two parts of cold water, the greater part of the other salts being left undissolved, as they are less soluble than the carbonate. The carbonate sold under the name of *Salt of Tartar*, is usually prepared in this way.

790. A pure carbonate of potassa is obtained by decomposing bitartrate of potassa (cream of tartar) by heat. It is occasionally mixed with nitre before it is decomposed, and the appearance and nature of the product vary according to the quantity employed, and the manner in which the operation is conducted. Another method of preparing a pure carbonate, by which also it is obtained perfectly dry, is to fuse the bicarbonate of potassa in a platinum crucible. It loses all its water of crystallization, and half of its carbonic acid.

791. When equal weights of nitre and cream of tartar are mixed together and thrown into a red-hot crucible, a rapid deflagration ensues, and a white matter remains, which is usually termed WHITE FLUX. It is a pure carbonate ; the nitric and tartaric acids of the two salts are completely decomposed, and part of the carbonic acid produced remains in combination with the potassa.

792. If two parts of the bitartrate are mixed with one of nitre, and the mixture thrown in quickly in successive portions, into a red-hot crucible, which is covered and luted whenever the materials have been introduced, a small aperture being left for the disengagement of gas, a black mass will remain in the crucible. This is composed of carbonate of potassa and charcoal, the oxygen in the nitric acid of the nitre not being sufficient to carry off the excess of carbon which the tartaric acid contains. It is usually termed BLACK FLUX. In preparing both these substances, a crucible, capable of containing twice the quantity of materials used, should be employed.

793. The white flux is used in several chemical operations to impart fluidity to different substances with which it is mixed at a high temperature ; the black flux may be employed for similar purposes, but it is used chiefly as a deoxidating agent, as in the reduction of arsenious acid.

794. When a pure solution of carbonate of potassa is required as a test, it should always be prepared from cream of tartar ; and if nitre be previously mixed with it, it should be free from salts of chlorine and other impurities.

795. This salt must always be kept in close vessels, to prevent it becoming liquid by attracting water from the air. Its solution renders the infusion of red cabbage green, and being much less caustic than pure potassa, the green colour remains for a considerable time. It is usually obtained in the form of an amorphous mass, and may be fused by exposure to a good red heat.

796. To prepare the BICARBONATE OF POTASSA, a stream of carbonic acid must be transmitted through a solution of the carbonate in Woulfe's or Nooth's apparatus. The solution must be evaporated by a very gentle heat, as the excess of acid is expelled by a boiling temperature. It crystallizes slowly in prisms, and is not altered by exposure to the air. It is used principally for effervescing draughts. About 75 grains of crystallized tartaric acid, or 76 grains of crystallized citric acid, can decompose 101 of the crystallized bicarbonate, combining with the potassa, and forming tartrate or citrate of potassa, which remains in solution, while the carbonic acid is disengaged with effervescence. Thirty or forty grains of tartaric acid, and a corresponding quantity of the bicarbonate, dissolved in sepa-

rate glasses of water, along with a few pieces of sugar, form an agreeable and refreshing draught when mixed together.

797. FERROCYANATE OF POTASSA *(or prussiate of potassa)*.— This salt is soluble in three parts of water at 60°, and in its own weight of boiling water. The solution affords large crystals of a beautiful yellow colour. It is not affected by the air, becomes black when exposed to a red heat, and is completely decomposed if kept at this temperature for some time. Its most important chemical relations are considered under cyanogen, hydrocyanic acid, and the red ferro-prussiate of potassa. Its solution gives no precipitate with alkalis or alkaline salts, but it decomposes some of the soluble earthy salts and most of the salts of the common metals when in solution, and is much employed as a reagent for detecting them.

798. ACETATE OF POTASSA is prepared by adding the purified acetic acid, procured from the distillation of wood, to car bonate of potassa in solution, till it is neutralized, evaporating the solution with great care afterwards, till the water is expelled ; the fused salt becomes a solid crystalline mass on cooling. By a high temperature it is completely decomposed. It is very soluble in water and deliquescent, and must be kept in close vessels.

799. TARTRATE OF POTASSA is very soluble in water, and is easily prepared from the bitartrate, by decomposing it with chalk in the manner described for the preparation of tartaric acid. Its solution affords crystals on evaporation.

800. The BITARTRATE OF POTASSA may be prepared by adding tartaric acid to a solution of the tartrate. But it is generally procured from the crude tartar that is deposited in wine casks, which consists of crystals of the bitartrate and colouring matter. By boiling it in water with charcoal, and alumina or compounds of this substance, such as clays, its solution is purified, and it is then crystallized or separated in successive pellicles from its hot saturated solution. It requires about seventy parts of cold and fifteen of boiling water for its solution.

801. The bitartrate of potassa of commerce usually contains a portion of the tartrate of lime, and is sometimes adulterated with other insoluble earthy substances, as carbonate of lime. By solution in water, and crystallization, it may be separated from these impurities.

802. CHLORATE OF POTASSA is soluble in about 18 parts of cold and in 2 or 3 of boiling water. It contains no water of crystallization; the theory of its formation and the method of preparing it have been described under chloric acid. It is particularly distinguished by the facility with which it gives oxygen to inflammable substances, and when exposed to heat, a large quantity of oxygen is disengaged, and chloride of potassium remains (36).

803. Mix a grain or two of the chlorate with a little sulphur in a mortar, and triturate them together; loud explosions take place, and the sulphur combines with the oxygen of the chloric acid.

804. Take a tenth of a grain of dry phosphorus and a grain of chlorate of potassa, put them together into a small piece of paper, strike it with a hammer, after folding it into a small packet and laying it on a stone or a block of iron; a larger quantity of materials should not be used, at least by the beginner, as part of the phosphorus is then apt to be thrown out in sparks. The detonation is violent, and the same reaction takes place as in the former case, the phosphorus combining with the oxygen of the acid. It should be struck so that any sparks of phosphorus are projected from the operator.

805. Introduce a little potassium into a jar of chlorine, using the copper cup represented by Fig. 73 (page 50); it takes fire immediately, combining with the chlorine, and forming CHLORIDE OF POTASSIUM. The same compound is procured when hydrochloric acid is added to a solution of the carbonate of potassa, and the solution obtained in this manner evaporated and crystallized; the carbonic acid of the carbonate is disengaged in the first place with effervescence, and the hydrogen of the acid unites with the oxygen of the oxide, forming water, while chloride of potassium remains in solution. It is soluble in three parts of cold water, and has a bitter saline taste. It is much used to furnish potassa in the preparation of alum.

806. IODIDE OF POTASSIUM may be formed by heating iodine and potassium in a small tube; heat and light are disengaged during their combination.

807. This important compound is usually termed the Hydriodate of Potassa, though it is now considered that such a combination can exist only in solution in water. One of the

best methods of preparing this substance consists in forming hy-
driodate of iron, and decomposing it by carbonate of potassa.
Hydriodate of potassa in solution is obtained, and, on evapora-
tion, iodide of potassium is procured.

808. To prepare hydriodate of iron, about 126 grains of iodine
and 50 or 60 of iron may be mixed in a Florence flask, with
two or three ounces of water, and heat applied by a lamp till
the liquid becomes clear. One equivalent of iron, with one of
iodine, decomposes one equivalent of water, and forms hydrio-
date of the oxide of iron, a reaction taking place in the manner
shewn in the annexed diagram.

Fig. 175.

Before Decomposition.			After Decomposition.
9 Water, .	{ Hydrogen,	1	127.5 Hydriodic Acid
	{ Oxygen,	8	
126.5 Iodine, ...126.5			
28 Iron,..... 28			36 Oxide of Iron.

Symb. ·H & I & Fe = H I + ·Fe.
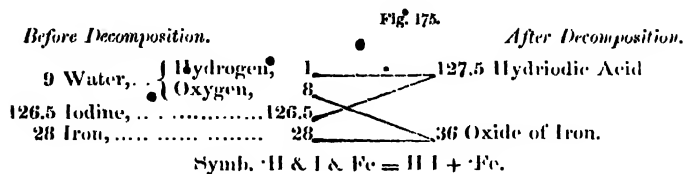
An excess of iron does no harm, presenting a large surface,
and causing the action to proceed more rapidly, while it is easily
removed by filtration.

809. The hydriodate of iron, being soluble, is dissolved by the
water, and on adding a solution of the carbonate of potassa to it,
taking care to use no more than is exactly necessary to decom-
pose it completely, carbonate of iron is precipitated, and hydrio-
date of potassa remains in solution ; the quantity required is
easily found out by adding small portions at a time as long as
any precipitate takes place. An equivalent weight of carbonate
of potassa may be taken for every equivalent of metal dissolved.

Symb. HI + ·Fe & :C + ·K = HI + ·K & :C + ·Fe.

810. When the solution is evaporated, and crystals procured,
the hydrogen of the hydriodic acid unites with the oxygen of the
potassa, forming water, and iodide of potassium remains. It is
more easily procured in crystals from its alcoholic solution.

Symb. HI + ·K = ·H & IK.
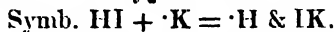
811. Many other processes have been recommended for the
preparation of this compound, but the method already described
is perhaps the most convenient that has been proposed. It may
be procured by the mutual action of iodine, potassa, and water.
Iodate and hydriodate of potassa are formed, part of the iodine

taking the oxygen, and the remainder combining with the hydrogen of part of the water which is decomposed; the reaction is similar to what ensues between chlorine, water, and potassa (or soda or baryta). The hydriodate of potassa is separated from the iodate by alcohol, in which the latter is insoluble; or, as Dr Gregory proposed, the iodate and hydriodate may be heated to redness, when both become iodide of potassium, oxygen being expelled from the iodate, and oxygen and hydrogen from the hydriodate.

812. It may be procured by the action of hydrosulphuric acid on a solution of potassa mixed with iodine ; but the method already described is the best.

813. Iodide of potassium deliquesces in a humid atmosphere, and is soluble both in water and alcohol. It has been frequently sold adulterated to a great extent with carbonate of potassa ; the presence of this substance is easily detected by its solution in water effervescing when diluted sulphuric acid is added to it, or by its alkaline reaction, turning vegetable-blues to a green. The amount of carbonate of potassa is estimated by the quantity of sulphuric acid required to neutralize it, every 40.1 of dry sulphuric acid used indicating 69.32 of carbonate of potassa.

814. BROMIDE OF POTASSIUM may be prepared by processes similar to those described for the preparation of the iodide. Heat gently two parts of bromine with one of iron filings in thirty parts of water, after having mixed the iron and bromine intimately with a little water, and allowed them to remain in contact for an hour. A solution of hydrobromate of iron is thus obtained, and to it two and a half parts of carbonate of potassa may now be added, having previously dissolved them in thirty parts of water. Carbonate of iron is precipitated, and hydrobromate of potassa remains in solution, which is resolved into water and bromide of potassium on crystallization.

CHAPTER II.—SODIUM.

Symb. Na.   *Eq. by W.* 23.5 ; *sp. gr.* 0.972.   *It is soft and mal-
leable at* 32°, *completely fused by a temperature of* 200°, *present-
ing the appearance of silver or mercury, and requires a good red
heat to convert it into vapour.*

815. Sodium may be prepared in the same manner as potas-
sium, or by mixing chloride of sodium with potassium, and dis-
tilling from an iron-retort, when the potassium combines with
the chlorine, and the sodium is volatilized.

816. Sodium bears a great resemblance to potassium in all
its chemical relations, and the experiments directed to be made
with potassium may be repeated with it, proceeding in the
manner we have already described.   It does not take fire, how-
ever, like potassium, when thrown on water, but in other re-
spects the action is precisely the same in both cases.   If, how-
ever, the water be thickened by dissolving gum in it, light and
heat are evolved when the sodium comes in contact with water.

Sect. I.—Soda.

Symb. ONa, *or* ·Na.   *Eq. by W.* 31.5 *(Oxygen* 8 + 23.5 *Sodium).*

817. Soda may be obtained from the carbonate of soda, by
the process described for the preparation of potassa from its
carbonate.   By evaporating the solution of soda in water, and
fusing the dry mass that remains, a hydrate of soda (·H + ·Na)
is obtained, similar to the hydrate of potassa in its general che-
mical relations.

818. Most of the experiments described under potassa may
be repeated with soda, but its solutions give no precipitate with
tartaric acid nor with bichloride of platinum.   Soda and com-
pounds of sodium in general also give an orange tint to the
flame of the blowpipe, an effect not produced by potassa or by
compounds of potassium.

SECT. II.—SALTS OF SODA, SULPHURET AND CHLORIDE OF
SODIUM, &c.

819. The salts of soda have the same general properties as
those of potassa, and all of them may be decomposed by this
alkali.   To see the greater affinity which potassa has for the
acids, pour a strong solution of this alkali into a saturated solu-
tion of the sulphate of soda ; crystals of sulphate of potassa are
soon formed.

820. The SULPHATE OF SODA (Glauber's Salt) is prepared
from the residuum of the preparation of hydrochloric acid, in
the same manner as the sulphate of potassa is procured from the
residuum of the distillation of nitric acid.   See 777.   It crystal-
lizes in prisms which are soluble in about three parts of water
at 56°, and in less than one-third of their weight of water at
90° ; an increase of temperature beyond this point, instead of
promoting, diminishes their solubility.   The crystals fuse on ex-
posure to heat, and part with their water of crystallization.
They effloresce when exposed to the air.   When a saturated so-
lution of sulphate of soda is kept at a high temperature, crystals
are deposited which contain no water of crystallization.   The
common crystallized sulphate contains ten equivalents of water.

821. Experiments may be made with sulphate of soda and
charcoal, with sulphuret of sodium and water, and with fused
soda, sulphur, and water, analogous to those described in the
paragraphs after sulphate of potassa, page 231, &c.

822. NITRATE OF SODA resembles nitre in its general pro-
perties and chemical relations.   But it is very deliquescent, and
hence cannot be used for gunpowder.   It is now used for the
preparation of nitric acid, and in the manufacture of sulphuric
acid.   It is a native production ; and is procured from South
America.

823. The CARBONATE OF SODA of commerce is obtained by
digesting in water Kelp or Barilla, the ashes of incinerated sea
plants, and crystallizing the solution.   It is also prepared by
soaking saw-dust, or other carbonaceous matter, in a strong so-
lution of the hydrosulphate of soda, and exposing the mixture
to heat in a reverberatory furnace.   The water is soon dissi-
pated. the hydrosulphuric acid is decomposed or expelled, and

Q

the soda combines with carbonic acid, formed by the combustion of the fuel, or of the materials with which the solution is mixed. The solution of the hydrosulphate used for this purpose is prepared from the sulphuret of sodium procured by decomposing sulphate of soda by charcoal, in the same manner as the sulphuret of potassium is obtained from its sulphate.

824. In many manufactories, the carbonate of soda is prepared from the sulphate by one operation. The sulphate of soda is decomposed by the charcoal, and sulphuret of sodium is formed ; by the continued action of the flame of the furnace and of the air, the sulphur is dissipated, and the sodium is oxidated and combined with carbonic acid ; so that, on boiling the resulting saline mass, filtering, and allowing the solution to cool, large crystals of the carbonate of soda are obtained.

825. By mixing carbonate of lime with the sulphate of soda and charcoal, the carbonate of soda is still more easily produced. See carbonate of potassa and its preparation from the sulphate.

826. In operations of this kind on the large scale, a REVERBERATORY FURNACE, of which there are many varieties, is generally used. The annexed figures* shew the manner in which they are constructed. In Figs. 176, 177, *a* is the furnace bars and fire-place*; *b*, the bridge or division between the fire-place
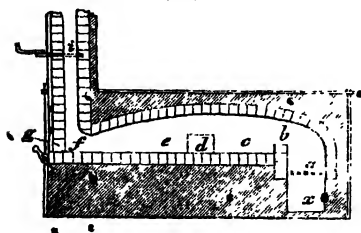
Fig. 176.   Fig. 177.
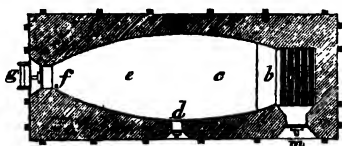
and the bed or floor of the furnace ; *e, c*, the bed of the furnace, which is heated by the flame and heated air passing under the arch before it escapes by the chimney at *f*; on it the materials are placed, which are introduced by the doors *d* and *g*. The doors are usually suspended by a chain passing over a pulley, a counterpoise or balance weight being attached to the other end of the chain ; *i* is a damper to regulate the draught.

From Mitscherlich's Chemistry.

827. The materials in the furnace require to be stirred or tossed about in some operations, which is effected by long iron bars or rakes, introduced from time to time at d and g. The doors d and g, may also be more or less opened or shut, according to the nature of the process, and by attending carefully to them, and also to the quantity and quality of the fuel used, the materials may not only be heated to any required temperature, but subjected also to a powerful *deoxidating* of smoky flame, or to the oxidating influence of the air.

·828. In Figs. 178, 179, the iron bars are represented, by which large reverberatory furnaces are usually bound, d is the side door, m the furnace door, x the ash-pit door, g the door at the extremity of the furnace.

Fig. 178.
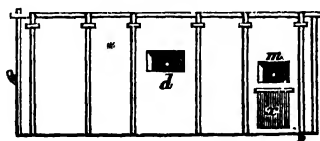
Fig. 179.
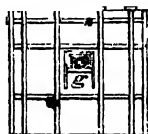
829. Carbonate of soda is easily obtained in large crystals, from its solution in water. They are soluble in two parts of cold water, and in less than their own weight of boiling water. On exposure to the air they effloresce, and fuse when heated, losing their water of crystallization. The quantity of water of crystallization which they contain, has been found to vary according to the temperature at which the crystals are formed ; the common crystallized carbonate contains in general ten or eleven equivalents of water. Its solution turns the vegetable blues to a green. It almost always contains a little sulphate of soda, the greater part of which may be removed by repeated crystallization ; but it is extremely difficult to free it entirely from the sulphate.

830. The SESQUICARBONATE OF SODA, generally called till lately the BICARBONATE, may be obtained in the same manner as the bicarbonate of potassa, and has similar properties. It has been ascertained, that the crystallized carbonate may be converted into the sesquicarbonate by the action of a current of carbonic acid more speedily than its solution in water, and that the process goes on still more rapidly, if the crystals be deprived of their water of crystallization by efflorescence.

831. Phosphate of Soda is prepared by adding carbonate of soda to a solution of the superphosphate of lime (352). The excess of phosphoric acid in the superphosphate combines with the soda of the carbonate, and remains in solution, disengaging carbonic acid with effervescence, while the phosphate of lime, having now lost its excess of acid, becomes insoluble, and is precipitated. The carbonate of soda ought to be added till the solution can render the test-paper green, as a slight excess of alkali favours the crystallization. The solution is filtered, to separate the phosphate of lime, and evaporated afterwards till a pellicle appears on its surface, when it may be set aside to crystallize.

832. Phosphate of soda is soluble in about four parts of water at 60°, and in two of boiling water. It has a saline taste, unaccompanied by the disagreeable bitterness of the sulphates of magnesia and soda. See phosphoric, pyrophosphoric, and metaphosphoric acids.

833. Chloride of Sodium or common salt, formerly called Muriate of Soda, exists abundantly in the mineral kingdom, forming immense beds, which are several hundred miles long in some places ; when obtained from these sources, it is termed Rock-salt. It may be prepared also in large quantities from sea-water, of which it constitutes the principal saline ingredient. In warm climates, the water is allowed to evaporate spontaneously in reservoirs made for the purpose, and the salt that remains is the Bay-salt of commerce ; in more northern regions, the water is dissipated in large pans or boilers. Occasionally, a large portion of the water is previously separated, when the temperature is very low, part of the water freezing, and leaving a stronger brine still liquid.

834. The salt procured by the spontaneous evaporation of sea-water is in large crystals, and much purer than what is prepared by rapid evaporation. The latter always contains a considerable quantity of magnesian salts, one of which, the hydrochlorate of magnesia, renders it deliquescent, and impairs its antiseptic properties.

835. The presence of magnesia may be easily detected, by adding a solution of the carbonate of soda to a solution of common salt in water ; a white precipitate appears immediately if magnesia be present (see Magnesia), while the liquid remains

transparent and colourless if there be none. By boiling the solution, the precipitation is more effectually induced.

836. When sodium is heated in chlorine, or in hydrochloric acid gas, the same compound is formed, hydrogen gas being disengaged when the latter is taken.

837. Chloride of sodium crystallizes in cubes or in hollow four-sided pyramids, which contain no water of crystallization chemically combined with them, but a small portion between the layers of the crystals, which is separated with decrepitation on exposure to heat. When a handful of bay-salt is thrown into the fire, it decrepitates with loud reports, and the larger crystals are thrown about with great violence.

838. Chlorine and soda combine, and form a compound which is much employed in solution as a disinfecting agent; Labarraque's disinfecting liquid owes its properties to this substance. Mr Phillips and Dr Faraday have examined it, and the latter has given the following formula for its preparation : 2800 grains of crystallized carbonate of soda are dissolved in 1.28 pints of water, and chlorine is then transmitted through the solution in Woulfe's apparatus, preparing it from 967 grains of common salt, 750 of the binoxide of manganese, and 960 of sulphuric acid diluted previously with an equal quantity of water; the chlorine should be transmitted through a bottle of pure water first, to remove any hydrochloric acid that may be mixed with it. No carbonic acid is disengaged, and though the solution contains chloride of soda, its precise composition has not been accurately ascertained. When long kept, it is in a great measure decomposed, chlorate and hydrochlorate of soda being formed by the reaction of the chlorine on part of the water, in the same manner as has been explained in 573.

839. TARTRATE OF POTASSA AND SODA is prepared by adding the bitartrate of potassa (cream of tartar), in fine powder, to a solution of the carbonate of soda in boiling water, as long as any effervescence takes place. Three hundred grains of the carbonate, dissolved in ten or twelve parts of water, is a sufficient quantity of this salt, to illustrate the nature of the process, and for this nearly four hundred grains of cream of tartar are required. The excess of acid which it contains unites with the soda of the carbonate, the carbonic acid being disengaged with effervescence, and the tartrate of soda remains in combi-

nation with the tartrate of potassa, the solution giving crystals when it is evaporated to a pellicle and set aside to cool. The following diagram gives a view of the reaction.

Fig. 180.

Before Decomposition.   *After Decomposition.*

Carbonate of { Carbonic Acid, 22.12--------------------22.12 Carbonic Acid.
" Soda........ { Soda.............. 31.5------------97.98 }
Bitartrate of { Tartaric Acid, 66.48------ Tartrate of Potassa
   Potassa ... { Tartaric Acid, 66.48------ and Soda.
         { Potassa.......... 47.2------113.68 }

Symb. : $C \cdot Na$ & $2T + \cdot K = :C$ & $T \cdot K + T \cdot Na.$
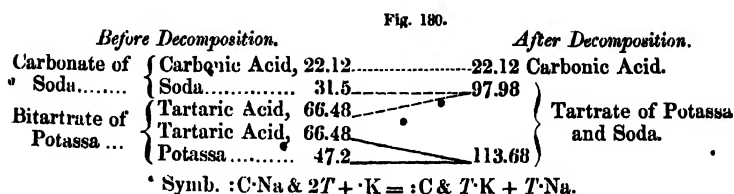
The solution gives large prismatic crystals, which are soluble in five parts of water.

840. The BIBORATE OF SODA, or Borax, is a native production, existing in the water of some lakes in Thibet and Persia. The crude borax met with in commerce, and known by the name of Tincal, is refined by solution and crystallization. It is often termed Subborate of soda, as its solution turns the vegetable blues to a green, two equivalents of boracic acid not being sufficient to neutralize one equivalent of soda.

841. This salt crystallizes in prisms, which are soluble in six parts of boiling and in twenty of cold water. When exposed to heat, its water of crystallization is expelled, and a transparent glass is obtained ; it is employed principally as a flux.

CHAP. III.—LITHIUM.

842. Lithium is the metallic base of Lithia, an alkali that was discovered by Arfvedson in 1818. Its chemical equivalent is 10, and the equivalent of lithia is 18, consisting of one equivalent of lithium and one of oxygen.

843. Lithia has been procured only in very small quantities, and has not been applied to any use. It is distinguished from potassa and soda, by forming with phosphoric and carbonic acids compounds which are only sparingly soluble in water.

CHAP. IV.—AMMONIA.*

Symb. NH^3. *Eq. by W.* 17.2 *(hydrogen* 3 + 14.2 *nitrogen) ; by vo-
lume* ▢ *(two measures). Sp. gr.* 0.59 ; *W. of* 100 *c. i.* 18.3
*grains. It is gaseous at natural temperature, but becomes liquid
when exposed to a pressure of six and a half atmospheres.*

844. Ammoniacal gas is prepared most easily from common
liquid ammonia (a compound of ammonia and water), by heating
it with a small spirit-lamp in a tubulated retort, and collecting
the gas over the mercurial trough, in the same manner as has
been directed for the preparation of hydrochloric acid gas. It
cannot be collected over a trough filled with water, as it is ab-
sorbed in large quantities by this fluid.

845. Should the student not have a mercurial trough, he may
prepare a small quantity of ammoniacal gas by displacement.
For this purpose, put two or three drachms of aqueous ammonia
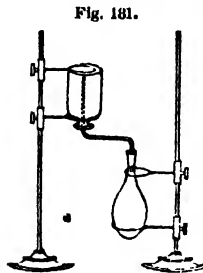
Fig. 181.

into a Florence flask, and adapt a bent glass-
tube to it, supporting it in the manner re-
presented in the adjoining figure. On heat-
ing the aqueous ammonia by a spirit-lamp,
ammoniacal gas is abundantly disengaged,
and may be collected by displacement in an
inverted jar or bottle, in the same manner
as sulphurous acid gas, 273, page 89. The
vessel in which the gas is collected must be
inverted, as it is lighter than atmospheric air. When the bottle
or jar is full of gas, a large quantity of dense white vapours are
formed on bringing a rod dipped in hydrochloric acid near the
mouth of the bottle, ammoniacal gas escaping after the air has
been expelled ; it must then be removed and corked tightly.
The bent tube is fitted to the flask by being passed through a
cork.

* This substance is placed along with the metals, though it contains no me-
tallic matter in its composition, as it bears a great resemblance to the oxides
of the alkaline metals in all its leading chemical relations, and as the student
will find it more convenient to examine its properties along with those of the
other alkalis.

846. Ammoniacal gas is transparent and colourless, and is easily distinguished by its peculiar pungent odour. It cannot support respiration or combustion. It inflames readily when mixed with oxygen gas, though it does not burn easily with atmospheric air. Ammonia possesses all the qualities of an alkali, affecting the vegetable colours in the same manner as potassa and soda. Its salts are all decomposed or volatilized by heat.

847. To see the great affinity that water has for ammonia, take a tube or bottle filled with this gas over mercury (266), or by displacement, and open it under water in a basin ; the ammonia is instantly condensed by the water, which rises into the tube and fills it completely, if the gas be quite pure. Dr Thomson states that water can take up 780 times its volume of ammonia at common temperatures.

848. When the gas is mixed with oxygen and inflamed, the mixture must be made over mercury in a strong jar or detonating bottle ; every two measures of ammoniacal gas (one equivalent) require a measure and a half of oxygen (three equivalents) for combustion, the hydrogen and the oxygen combining together, and forming water, while the nitrogen is disengaged.

849. Ammonia is decomposed by chlorine, which, combining with its hydrogen, forms hydrochloric acid, and disengages nitrogen ; if an excess of ammonia be used, the hydrochloric acid combines with it, and forms hydrochlorate of ammonia.

Fig. 182   The mixture may be made over the mercurial trough ; or a bottle full of chlorine may be connected with a bottle full of ammoniacal gas (Fig. 182), by a glass-tube passing through a cork that fits them both, placing the bottle containing the ammonia uppermost. Three measures of chlorine are required for the complete decomposition of two measures of ammonia. A lambent flame accompanies the action. The chlorine may be prepared in the vase or bottle at a pneumatic trough filled with water, and the vase of ammoniacal gas may be filled by displacement. The glass-tube passing through the connecting cork, should not be above one-third of an inch in diameter. After putting it into the vase with chlorine gas, invert the other containing the ammoniacal gas, remove its

cork, and place it over the other extremity of the tube, in the manner represented in the figure. Vases or bottles capable of containing from a few to 100 or more ounce measures may be taken for this experiment.

850. Ammonia is easily recognised by its odour, and by the white fumes of hydrochlorate of ammonia which are formed, when a glass rod dipped in hydrochloric acid is brought in contact with it. When its solution in water is too dilute to give any perceptible smell, it may in general be easily detected by the deep blue colour which it produces with a solution of a salt of copper. See Copper.

851. The water of ammonia (common liquid ammonia, or aqueous ammonia), usually termed *spirit of hartshorn*, or volatile alkali, is prepared on the large scale by the decomposition of animal matter exposed to heat in close vessels, condensing the product in water; but it is obtained most conveniently by decomposing hydrochlorate of ammonia by slaked lime, receiving the product into water kept cold in a bottle receiver. For this purpose 2 parts of quicklime and 3 of hydrochlorate of ammonia are mixed together, after the former has been slaked with half of its weight of water and allowed to cool; they should both be in fine powder, and intimately blended, taking care to avoid the pungent fumes that are disengaged. The mixture is then put into an iron-retort (an iron bottle with a bent tube fitted to it, will do equally well), and placed in a sand-bath. The beak of the retort is then luted to a quilled globe, of the form re-

Fig. 183
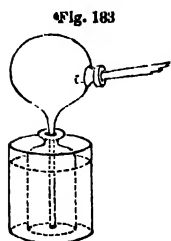
presented in the annexed figure, making the joining tight with a little chalk lute; and a quantity of water, equal in weight to three-fourths of the hydrochlorate of ammonia which is used, is put into a bottle or receiver. The tube from the globe should reach to the bottom of the bottle, which should not be more than half full, when the proper quantity of water has been put in. The use of the glass globe is to allow air to pass into the retort as the apparatus becomes cold, and prevent any of the water of ammonia from being carried along with it; for, whenever the ammoniacal gas ceases to come, and all the liquid in the bottle has been forced into the globe by the pressure of the atmosphere as the remaining gas is condensed, then air

enters by the small quill tube, and passes through the water of ammonia to the retort. It must be kept in bottles with good glass stopples, otherwise much of the ammoniacal gas soon escapes.

852. Green glass-retorts, or even flint glass-retorts, may be employed, instead of iron vessels; but the latter should always be preferred, when they can be obtained. Earthen retorts, also, are occasionally used. A small quantity of materials may be taken; from an ounce to a pound, as may be found most convenient.

853. In this process, the lime combines with the hydrochloric acid of the hydrochlorate of ammonia, and disengages ammoniacal gas, which is condensed by the water; a reaction at the same time takes place between the lime and the hydrochloric acid, and the products are, chloride of calcium and water. The diagram gives a view of the decomposition.

Fig. 184.

Before Decomposition.   *After Decomposition.*

53.7 Hydroch. ⎰ Ammonia, ...17.2 ─ ──────17.2 Ammonia.
of Ammonia ⎱ Hydroch. A. ⎰ Hydrogen. 1────9 Water.
          ⎱ Chlorine. ...35.5
28.5 Lime,.................. ⎰ Oxygen...... 8
          ⎱ Calcium... 20.5────56 Chlor. of Cal.

Symb. HCl + NH³ & ·Ca = NH³ & ·H + ClCa.
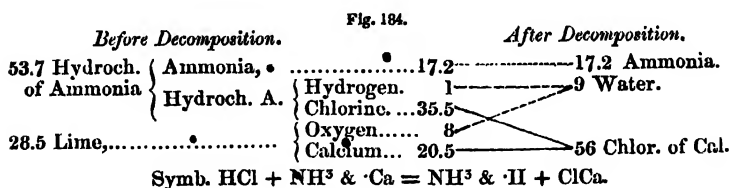
The lime is employed in larger quantity than is absolutely necessary for the decomposition, in order that it may be more easily affected; it is unnecessary to represent the excess in the diagram, however, as it is not decomposed.

854. The specific gravity of the water of ammonia varies according to the quantity of water employed to condense the ammoniacal gas. The following table by Sir Humphrey Davy shews the quantity of dry alkali which it contains at different densities.

Specific gravity.	Ammonia in 100 pts.	Specific gravity.	Ammonia in 100 pts.	Specific gravity.	Ammonia in 100 pts.	Specific gravity.	Ammonia in 100 pts.
.8750	32.50	.9166	22.07	.9435	14.53	.9573	10.82
.8875	29.25	.9255	19.54	.9476	13.54	.9597	10.17
.9000	26.00	.9326	17.52	.9513	12.40	.9619	9.60
.9045	25.37	.9385	15.88	.9545	11.56	.9692	9.50

855. The impurities commonly met with in the ammonia of commerce, are hydrochloric, sulphuric, and carbonic acids, and occasionally a portion of oily matter, derived from the animal matter from which it is at first procured.

856. To detect hydrochloric acid, dilute a small portion of the ammonia with 10 or 12 times its bulk of water, add nitric acid in excess, and then a solution of the nitrate of silver, which immediately gives a precipitate of the chloride of silver, should there be any hydrochloric acid present.

857. To detect sulphuric acid, dilute another portion, and saturate with nitric acid as before ; then add a solution of the hydrochloric or nitrate of baryta, when sulphate of baryta is precipitated, if the ammonia contain any sulphuric acid.

858. The oily matter may be detected occasionally by its empyreumatic odour, and, when present only in very minute quantity, by adding very cautiously, and in small quantities at a time, a great excess of sulphuric acid : any oily or other animal matter is indicated some time afterwards, by the dark colour which the liquid assumes, a small portion of carbon being eliminated.

859. To procure the ammonia free from these impurities, expose it to a very gentle heat in a retort, and condense the gas that is disengaged in distilled water, in the manner shewn in 851.

860. Alcohol has a great affinity for ammoniacal gas, and can condense a large quantity of it. *Alcohol ammoniatum*, of the Edinburgh College, is prepared by transmitting ammonia, obtained by the decomposition of hydrochlorate of ammonia, through alcohol, instead of water.

Salts of Ammonia.

861. The method of preparing the NITRATE OF AMMONIA has already been described under Oxide of Nitrogen, page 47. It is deliquescent, and very soluble in water. It may be obtained in the form of prismatic crystals, by stopping the evaporation of its solution in water when a drop, taken out on a glass rod, crystallizes in slender prisms as it cools ; or, in the form of a fibrous mass, by continuing the heat till the drop taken out becomes quite solid on cooling, when most of the water will

have been expelled. It is decomposed by a temperature be-
tween 400° and 500°, being resolved into oxide of nitrogen and
water.

862. SULPHATE OF AMMONIA is obtained most easily, by neu-
tralizing the carbonate of ammonia by sulphuric acid diluted
with five or six parts of water. The sulphate of ammonia is
found in soot, being formed during the combustion of the coal,
volatilized, and deposited along with the soot. It may be sepa-
rated by lixiviation : and was extensively used for the manufac-
ture of sal-ammoniac (874).

863. HYDROSULPHATE OF AMMONIA, called also HYDROSUL-
PHURET OF AMMONIA, is prepared most conveniently by transmit-
ting a stream of hydrosulphuric acid gas through common liquid
ammonia, diluted with several times its bulk of water. The hy-
drosulphuric acid gas is absorbed rapidly by the ammonia ; it
may be prepared in the usual manner, 315, page 102, using 44.1
parts of sulphuret of iron for every 17.2 of dry ammonia in
the liquid ammonia employed. The apparatus represented by
Fig. 82, page 68, will be found very convenient for the prepa-
ration of this compound, preparing the gas in the first bottle,
and putting the ammonia into the other. Its odour is extremely
fetid and disagreeable, and its colour varies from a greenish-
yellow to an orange tint. It is much employed as a test for de-
tecting many of the metals.

864. When hydrosulphuric acid and ammoniacal gases are
brought into contact with each other, crystals are immediately
formed. The apparatus described in 297, page 95, may be used
for this experiment.

865. PHOSPHATE OF AMMONIA is used principally for the pre-
paration of pure phosphoric acid, and may be obtained in the
manner described in 389, page 123.

866. CARBONATE OF AMMONIA may be obtained, by mixing
two measures of ammonia (one equivalent) with one measure of
carbonic acid (one equivalent) over mercury ; the two gases
immediately combine, and condense in the form of a white dry
powder.

867. BICARBONATE OF AMMONIA may be prepared, by passing
a stream of carbonic acid gas through a solution of common
carbonate of ammonia, till it ceases to absorb any more, and
evaporating the liquid by a very gentle heat.

868. The Subcarbonate of Ammonia of the Pharmacopœia, called Sesquicarbonate of Ammonia by Mr Phillips, and usually sold under the name of Carbonate of Ammonia, is composed of carbonate and bicarbonate of ammonia. It is prepared by mixing one part of hydrochlorate of ammonia and one part and a half of carbonate of lime, both reduced to a fine powder, and exposing the mixture to a strong heat in an iron pot, covered by a dome or head, on which the subcarbonate condenses as it is sublimed; should the carbonate of lime employed be damp, it ought to be well dried before mixing it with the hydrochlorate of ammonia. The process is imitated most easily on the small scale, by exposing an ounce or two of the mixture to heat in an iron tube closed at one end, and placed horizontally, the other extremity being connected to a glass-tube or receiver, which is kept quite cold. An earthen retort may be employed for the same purpose.

869. Here the carbonic acid of the carbonate unites with the ammonia of the hydrochlorate, and forms the carbonate of ammonia, the hydrochloric acid and lime reacting on each other, and producing chloride of calcium and water. This part of the action is shewn in the diagram.

Fig. 185.

Before Decomposition.				After Decomposition.
53.7 Hydrochlorate of Ammonia, ...	{	Ammonia	17.2	39.32 Car. of Am.
	{	Hydrochlor. { Hyd.	1	.9 Water.
	{	Acid ...... { Chlo.	35.5	
50.62 Carbonate of Lime, ...	{	Carbonic Acid	22.12	
	{	Lime { Oxygen	8	
	{	{ Calcium	20.5	56 Chlo. of Calc.

Symb. HCl + NH^3 & :C·Ca = :C + NH^3 & ·H & ClCa.
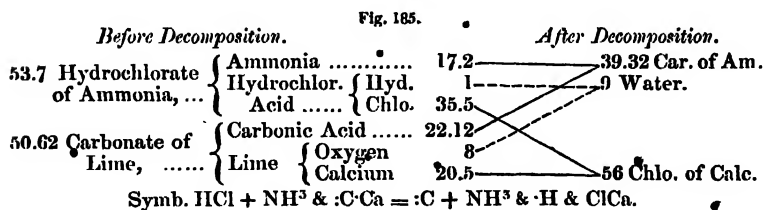
But the product is not a pure or dry carbonate of ammonia. It consists of carbonate and bicarbonate, part of the carbonate formed losing ammonia and giving its carbonic acid to a portion which is not decomposed; and it contains also a portion of water. It consists of two eqs. of ammonia, three of carbonic acid, and two of water.

870. This salt is semitransparent when newly prepared, and has a crystalline texture and pungent odour; it parts with a portion of its ammonia on exposure to the air, and is converted ultimately into the bicarbonate. It is soluble in two parts of

cold water. Its solution turns the vegetable colours to a green, and, when exposed to heat, part of the salt is carried away with the watery vapour that is formed.

871. The Dublin College recommends this compound to be prepared from dried carbonate of soda and hydrochlorate of ammonia, mixing them in equal weights, and heating them in an earthenware retort; the product may be condensed in a glass receiver. The reaction that takes place is precisely similar to that which ensues in the preceding case, substituting 53.62 parts of carbonate of soda for the 50.62 of carbonate of lime represented in the diagram ; chloride of sodium remains, water and the ammoniacal carbonate being expelled.

872. OXALATE OF AMMONIA is prepared by adding the common carbonate of ammonia to a solution of oxalic acid in water till it is neutralized. Needle-shaped crystals are obtained on concentrating the solution by evaporation, and allowing it to cool. This salt is much employed to detect and estimate the quantity of lime in solutions.

873. HYDROCHLORATE OF AMMONIA, called also MURIATE OF AMMONIA or SAL-AMMONIAC, is manufactured in large quantity for use in the arts, and it is seldom necessary to prepare it in the laboratory. Equal measures of hydrochloric acid and ammoniacal gases, however, may be mixed over the mercurial trough to shew its formation, or the two gases may be made to meet in a large glass vessel, preparing them by exposing water of ammonia and common hydrochloric acid to heat in retorts connected with it, in the manner shewn in 297, page 95.

874. On the large scale, this salt is obtained by steeping animal matters in a strong solution of the hydrochlorate of magnesia, and exposing them to heat after they have been dried, so as to undergo a kind of slow combustion. The hydrochloric acid leaves the magnesia, and combines with ammonia, formed by the decomposition of the animal matter. This is Mr Astley's ingenious process for the preparation of this valuable salt. It is also procured by adding hydrochloric acid to the impure carbonate of ammonia, obtained during the preparation of coal gas ; and likewise from the reaction of chloride of sodium and sulphate of ammonia with water, sulphate of soda and hydrochlorate of ammonia being formed. It is purified by repeated sublimation.

875. Hydrochlorate of ammonia is soluble in rather less than

three parts of water at 60°, and produces cold during its solution. Boiling water dissolves its own weight of this salt, and very beautiful feathery looking crystals are obtained when it cools. It is sparingly soluble in alcohol. When exposed to a temperature above 300°, it sublimes slowly without decomposition.

876. When equal weights of hydrochlorate and nitrate of ammonia are fused together between two watch glasses, the under glass is much corroded, the alkali being removed, and the silica left. This effect is produced with the nitrate alone ; but, when the nitrate and hydrochlorate are mixed together, the effect is much more powerful.—(Silliman's Journal, vol. xviii.)

ORDER II.—TERRIGENOUS METALS.

CHAP. I.—CALCIUM AND ITS COMPOUNDS.

Symb. Ca ; *Eq. by W.* 20.5.

877. CALCIUM is the name given to the metallic base of lime, which is composed of this substance and oxygen. It has been procured hitherto only in very small quantities, by decomposing carbonate of lime by a galvanic battery. The method of proceeding is to make the carbonate into a paste with water, and place it on a platinum-tray connected with the positive pole of the galvanic battery, putting a globule of mercury in a small cavity on its surface, and bringing it in contact with a wire from the negative pole. The lime in the carbonate is decomposed, its oxygen being disengaged, and the calcium attracted to the negative pole, where it combines with the mercury, and forms

an amalgam ; by exposing this to heat, the mercury is volatilized, and the calcium remains.

878. Lime (OCa, or ·Ca ; Eq. 28.5 = O. 8 + 20.5 Ca) is the most important compound of calcium, and is usually procured by exposing the carbonate of lime to a red heat, when its carbonic acid is completely expelled. For many chemical purposes, the lime that is employed for mortar does very well ; but when it is required in a purer form, it is obtained most easily by exposing white marble to heat in a crucible placed in a furnace for two hours ; or, if a larger quantity should be required, it will be found more convenient to put a good fire in the furnace, and then to fill it up with alternate layers of coals and white marble, broken into pieces not more than an inch, or an inch and a half thick, and from one to three or four inches long, taking care to build them in such a manner, as may allow the fire to burn slowly and steadily. When the intervening spaces are too open, and the draught of the furnace very great, the fuel is speedily consumed, and only the external parts of the marble are decarbonated ; and if a very strong fire be kept up for a considerable time, instead of obtaining the lime in solid masses of the same form as the marble put in, it generally falls into powder, which mixes with the ashes of the fuel. Carbonate of lime is decomposed very imperfectly in crucibles, where it is surrounded by an atmosphere of carbonic acid. If steam be passed over the carbonate, it favours the expulsion of the gas by displacing the carbonic acid, when separated from the lime.

879. Pure lime, termed also *caustic lime*, or *quicklime*, has a fine white colour, and an earthy appearance ; its taste is burning and alkaline ; it corrodes animal and vegetable substances, is easily reduced to powder, and must be kept in close vessels, as it soon attracts water and carbonic acid from the air, crumbling down into a fine powder.

880. When water is poured upon lime, it combines with it immediately, forming *hydrate of lime*, and great heat is produced during the combination ; the compound is quite solid, though in the form of a bulky powder, and is usually termed *Slaked lime*. Every 28.5 parts of lime combine with 9 of water. By exposure to the air, the hydrate soon attracts carbonic acid, so that it is necessary to keep it in close vessels.

881. Lime is sparingly dissolved by water, but in sufficient

quantity to impart its characteristic properties to this fluid. The solution, which is known by the name of *lime water*, is made by agitating slaked lime repeatedly with water in a bottle, pouring off the clear liquid when the excess of lime has been deposited. It turns the blue infusion of cabbage to a green, and turmeric to a brown. It gives a precipitate of carbonate of lime with carbonic acid water, or by breathing through it with a bent tube, if the carbonic acid be not added in excess. (See 450–1–2.) It gives no precipitate with sulphuric acid, as sulphate of lime, though only very sparingly soluble in water, is more soluble than lime itself.

882. Boil some lime-water in a Florence flask ; part of the lime is precipitated, as it is more soluble in cold than in hot water. According to Dr Dalton, one part of lime requires upwards of 700 parts of cold water for its solution, and boiling water dissolves little more than half that quantity. Mr Phillips states that

A pint at 32° dissolves 13.25 grains of lime.
  ... 60° ... 11.6 ...
  ... 212° ... 6.7 ...

883. The student should now make a variety of experiments to render himself familiar with the nature of lime, the substances that are incompatible with it, and the appearances presented by their action upon it in the solid form, or in solution. Many of these will naturally suggest themselves : one or two may be mentioned.

884. Pour some sulphuric acid on a little quicklime in an iron cup, taking care to avoid the fumes ; sulphate of lime is formed, and the heat produced by the combination is so great, that part of the sulphuric acid is volatilized. This experiment should be made in the open air, or, the cup containing the lime may be placed under the chimney. If a little gunpowder be thrown upon it immediately after the sulphuric acid has been added, it will be inflamed.

885. Add a little carbonate of lime to diluted nitric or hydrochloric acid ; the acid unites with the lime, and the hydrochlorate of lime formed remains in solution, the carbonic acid being disengaged with effervescence.

886. Add a little sulphuric acid to about an equal bulk of a saturated solution of hydrochlorate of lime ; sulphate of lime is

formed, copious fumes of hydrochloric acid are disengaged, and a solid mass of sulphate of lime remains. Dilute the acid and the solution previously with equal bulks of water, and mix them together, after allowing the acid to cool : the mixture becomes nearly solid, sulphate of lime being formed as before, and the water mixed with it retains almost all the hydrochloric acid in solution. If, however, the solution be diluted with about 500 or 600 parts of water, then no precipitation takes place, the sulphate of lime being soluble in the quantity of water now present.

887. Oxalic acid is the most delicate test of lime, the oxalate of lime being less soluble in water than any of its other salts. Drop a small quantity of oxalic acid into lime water ; a copious precipitate of the oxalate of lime immediately appears. Add a little oxalic acid to a solution of the sulphate of lime ; a slight precipitate only appears, and, if an excess of sulphuric acid should have been previously mixed with it, no apparent change takes place. The reason is, that sulphuric acid has a stronger affinity for lime than oxalic acid ; if, however, ammonia, soda, or potassa be added to neutralize the sulphuric acid, then the oxalic acid combines at once with the lime, and a copious precipitate appears.

888. Hence, oxalate of ammonia, or oxalate of potassa, is employed in preference to pure oxalic acid for precipitating lime from its solutions ; and when an excess of acid is present, it must be neutralized before we begin to apply our tests.

889. But oxalic acid does not distinguish lime from baryta or strontia, as the oxalates of the latter earths are also extremely insoluble. Where either of these may be suspected, the precipitate is to be dissolved in dilute nitric acid, and crystals procured by evaporation. The nitrate of lime appears in prisms, is soluble in alcohol, and very deliquescent. The nitrates of baryta and strontia yield octohedral crystals, are not soluble in alcohol, and are very slightly deliquescent.

890. Add a solution of potassa, or soda, to a solution of any soluble salt of lime ; the alkali unites with the acid, and lime is precipitated. Add a little carbonate of potassa, or of soda, to lime water or to a salt of lime in solution ; carbonate of lime is precipitated, and, when the lime has been combined with an acid, the potassa or soda unites with it, as in the preceding experiment, and remains in solution.

891. Add a solution of pure ammonia to a solution of a salt of lime, as the sulphate, the nitrate, or the hydrochlorate ; the ammonia does not precipitate the lime.

SALTS OF LIME, CHLORIDE OF CALCIUM, &c.

892. SULPHATE OF LIME may be formed by the action of diluted sulphuric acid on lime, or on the carbonate of lime ; but, as it is an abundant production of nature, it is seldom prepared artificially. Anhydrite consists of dry sulphate of lime. Gypsum, Selenite, and Alabaster, are compounds of one eq. of sulphate of lime and two of water. Sulphate of lime is soluble in about 500 parts of water. It is the most common cause of the *hardness* of spring or well water.

893. PLASTER OF PARIS is prepared by expelling the water with which sulphate of lime is usually combined, exposing it to a dull red heat for several hours, after which, it is ground to a fine powder, and mixed with a sufficient quantity of water to give it a thick consistence ; the best method of doing this, is to take a quantity of water, and to pour in the dry sulphate till most of it is absorbed ; it may then be stirred and used before it begins to turn thick. The hardening arises from the water combining intimately with the sulphate, and forming a solid compound, in the same manner as when quicklime combines with this fluid.

894. Sulphate of lime may be decomposed, by heating it with charcoal in a crucible ; SULPHURET OF CALCIUM is obtained, while carbonic oxide is disengaged ; when this is digested in water, a solution of the hydrosulphate of lime is obtained. The reaction that takes place in both these cases will be easily understood, on referring to 780 and 784, where the theory of the preparation of sulphuret of potassium and hydrosulphate of potassa, from sulphate of potassa by charcoal, has been minutely explained ; and diagrams representing the decomposition may be constructed in the same manner, only substituting calcium and lime, with their corresponding equivalents &c., for potassium and potassa.

895. The SULPHURETED HYDROSULPHATE OF LIME has been described in the section on bisulphureted hydrogen.

896. NITRATE OF LIME may be formed by adding carbonate

of lime to diluted nitric acid, the carbonic acid escaping with effervescence. Crystals may be obtained, by evaporating the solution to the consistence of a syrup, and cooling it slowly. It is very deliquescent, and is sometimes employed to abstract water from bodies. It dissolves in about one-fourth of its weight of water at 60°. It is found in old mortar, and is the first product in the operation for preparing nitre (761).

897. PHOSPHATE OF LIME is most easily obtained, sufficiently pure for ordinary purposes, by exposing bones to a red heat in an open fire, till all the animal matter which they contain is destroyed. It is insoluble in water, but, by an excess of phosphoric acid, it is easily dissolved. (See 352). See also Phosphoric Acid. It may be dissolved also, without being decomposed, in diluted nitric or hydrochloric acids.

898. PHOSPHURET OF CALCIUM is formed, whenever phosphorus is brought into contact with lime at a high temperature. The easiest method of preparing it, is, by throwing a piece of dry phosphorus into a crucible with a few fragments of lime (each about the size of a pea or rather larger) at the bottom, and at a bright red heat, an assistant putting on a cover, or inverting the crucible immediately on a flat plate of iron, at the same time throwing a quantity of sand round it to close any aperture. The experiment may be made easily with 20 or 30 grains of phosphorus, and about 60 or 70 of lime in a small crucible. It may also be formed, by transmitting phosphorus in vapour over lime in a porcelain tube, in the apparatus shewn in Fig. 153, page 164; no receiver, however, is required, and a much smaller retort should be used. A chauffer may be used in place of a furnace for heating the tube, Fig. 31, page 20; and, instead of heating the phosphorus in a retort, it may be put in at one extremity of the tube on commencing the process, closing it immediately afterwards with clay. When the lime is sufficiently heated, the tube must be drawn gently a little way through the furnace, so that the phosphorus shall now be melted and converted into vapour; the end at which it is introduced having been closed, it is forced over the heated lime.

899. In these processes, part of the phosphorus unites with the oxygen of part of the lime, and the resulting compound combines with a portion of lime not decomposed. The remainder of the phosphorus, excepting a portion which escapes, attaches

itself to the calcium of the lime that is decomposed, forming the phosphuret of calcium, which remains mixed with the first compound. From an examination of the resulting product, it has been considered that the calcium is united in this compound with two equivalents of phosphorus; its proper appellation, therefore, is *biphosphuret of calcium*, though the other term is that which has been generally adopted.

900. CARBONATE OF LIME is an abundant production of nature, marble, chalk, limestone, coral, shells of shell-fish, and a variety of other substances, being composed almost entirely of this compound. Carrara marble and Iceland spar are the purest natural varieties of carbonate of lime. Some of the others contain occasionally a considerable quantity of foreign matter. It is precipitated from a solution of salts of lime by alkaline carbonates. It is extremely insoluble in water. But the bicarbonate is sparingly soluble, so that water containing carbonic acid can take up a little of the carbonate of lime.

901. HYDROCHLORATE (MURIATE) OF LIME is prepared, by dissolving carbonate of lime in diluted hydrochloric acid, carbonic acid being disengaged with effervescence. On evaporating the solution to dryness, it is converted into chloride of calcium, the hydrogen of the acid combining with the oxygen of the oxide, and forming water, while the chlorine remains in combination with the calcium.

Fig. 186.

Before Decomposition.			After Decomposition.
36.5 Hydrochloric Acid,	{ Hydrogen	1	9 Water.
	Chlorine	35.5	
28.5 Lime,	{ Oxygen	8	
	Calcium	20.5	56 Chloride of Calcium.
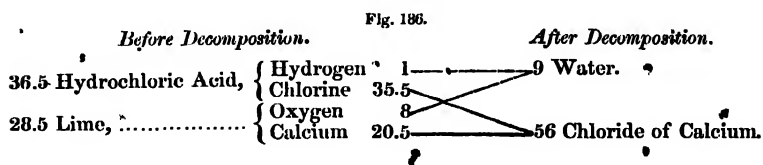
On putting it into water, it is supposed to be again converted into hydrochlorate of lime as it is dissolved.

902. The CHLORIDE OF CALCIUM deliquesces rapidly on exposure to the air, has a very bitter and disagreeable taste, and is dissolved by about one and a half times its weight of water; its solution in this fluid gives large crystals, which contain a considerable quantity of water of crystallization. It is also soluble in alcohol, and imparts a red colour to its flame when it is kindled.

903. The crystals prepared from its solution in water pro-

duce a great reduction of temperature, when pounded and mixed with dry snow, and are accordingly much employed for freezing mixtures, when a very low temperature is required. Instead of reducing the crystals to powder for this purpose, it is better to prepare the chloride at once in the form of a powder, by evaporating its solution till it becomes so strong, that, on taking out a drop on the end of a glass rod, it becomes quite solid on cooling; then it may be removed from the fire, and, after allowing it to cool for a short time, let it be agitated constantly, in a large plate or earthen mortar, till it assumes the form of a dry powder. This ought to be begun before any of the solution has consolidated ; and when the powder has been prepared, it must be kept carefully excluded from the air till it is required for experiment. From its great affinity for water, it is employed to abstract the watery vapour from gases. For this purpose, it is fused and broken into small fragments.

904. CHLORIDE OF LIME is a very different compound from the chloride of calcium. It is employed extensively in bleaching. It is prepared on the large scale, by exposing slaked lime to the action of chlorine gas, which combines with it ; the combination is attended with the evolution of heat, which is very apparent where the absorption of the gas proceeds rapidly. A solution which may be used for all the purposes to which this compound is usually applied, may be procured by transmitting a current of chlorine, prepared from an ounce or two of the binoxide of manganese with the proper quantity of hydrochloric acid (529), through two ounces of the hydrate of lime suspended in 12 or 14 ounces of water. A similar solution may be obtained by dissolving in water the chloride of lime of commerce. In the state in which it is usually met with, it may be regarded as a hydrate of lime, combined with various proportions of chlorine. It has lately been considered as composed of a mixture of chloride of calcium and hypochlorite of lime.

905. When the chloride is exposed to heat, a considerable quantity of chlorine is disengaged at first, which is succeeded by oxygen gas, a portion of chloride of calcium then being formed. The same change is believed to take place when it is kept for a long time even in the dark, and in close vessels, so that, on opening a bottle full of this compound which has been accurately closed for a considerable time, a quantity of oxygen

often escapes, and sometimes throws some of the chloride out of the bottle ; when the bottle has been kept in a warm place, the chlorine that is disengaged often produces the same effect, so that the experimenter must always bear this in mind, to prevent any of it being thrown in his eye, an accident that occasionally happens on taking out the cork inadvertently. When exposed to the air, chlorine is slowly evolved, carbonic acid being absorbed.

906. The solution of the chloride of lime is applied to the same purposes as the solution of chlorine in water. Acids decompose it, combining with the lime, and disengaging chlorine. It generally contains an excess of lime. To obtain the full benefit of the chlorine in discharging vegetable colours, an acid must be added to it to combine with the lime, and set the chlorine at liberty. Dilute sulphuric acid, or tartaric acid, is generally employed.

907. As the value of chloride of lime depends on the quantity of chlorine which it contains, and as this varies considerably, depending not only on the care used in preparing it, but also on the precautions taken to preserve it, several methods for ascertaining its strength have been proposed. One consists in adding a given quantity of the diluted solution to a solution of indigo in sulphuric acid of a known strength ; the strength of the chlorine being indicated by the quantity of the solution which it can decolorize.—*Quarterly Journal, New Series,* vol. vi.

908. It has also been proposed to ascertain the quantity of chlorine in chloride of lime, by observing the quantity of nitrogen gas which is disengaged, when it is made into a paste or cream with water, and mixed with fragments of hydrochlorate of ammonia ; the lime combines with the hydrochloric acid, and forms hydrochlorate of lime, while the chlorine takes hydrogen from the ammonia, and disengages nitrogen.

909. If chloride of lime be introduced into a glass-tube full of mercury, and inverted in a cup or basin of this fluid, and hydrochloric acid be then introduced, hydrochlorate of lime is formed, and the chlorine which is disengaged may be measured. But there is no process, perhaps, so generally resorted to for ordinary purposes as the first.

•CHAP. II.—BARIUM AND STRONTIUM.

SECT. I.—BARIUM.

Symb. Ba.   *Eq. by W*. 68.6.

910. BARIUM is a dark grey coloured metal, which has been procured only in very minute portions, and by a process similar to what has been described for the preparation of calcium.   Its specific gravity is greater than that of sulphuric acid.   It quickly oxidizes in the air ; and also in water, hydrogen being evolved.

BARYTA OR BARYTES.

Symb. OBa, *or* ·Ba.   *Eq. by W.* 76.6 (O.8 + 68.6 Ba).

911. BARYTA is composed of one equivalent of barium and one of oxygen, and is accordingly represented by the number 76.6. .It is obtained most easily from the nitrate, by exposing it to a dull red heat in a crucible, the nitric acid being then completely expelled.   The crucible should not be filled more than half full, and the heat is to be continued for one or two hours ; a few grains will be sufficient to shew the decomposition, but when it is required to crystallize the baryta, an ounce or two of the nitrate should be taken.

912. Baryta may also be obtained from the carbonate of baryta, as Dr Hope pointed out ; but a much higher temperature is required to drive off the carbonic acid, than is necessary for the decomposition of carbonate of lime.   The carbonate should be reduced to fine powder for this purpose, and mixed with one-fourth part of its weight of charcoal ; the mixture is then made into a ball, with a little tar or other inflammable matter, and exposed to a full white heat in a black-lead crucible for two hours.

913. Baryta is similar to lime in all its leading properties. It differs from it principally in being much more soluble in

water, producing a still greater heat when it is slaked, and forming salts which are less soluble than those of lime. The hydrate of baryta, prepared by slaking it with water, is soluble in 3 parts of boiling water, and 20 of water at 60°. A saturated hot solution gives crystals as it cools. They are obtained most easily by adding boiling water to it as soon as it is slaked, till the milky powder that is formed is covered with this fluid, mixing them in a thin glass flask, capable of bearing a sudden heat. The crystallized hydrate contains 20 equivalents of water combined with one of baryta according to Dalton, 9 or 10 according to others. The solution is an extremely delicate test of carbonic acid.

914. Baryta has an acrid taste, and corrodes animal and vegetable substances, but its causticity is much inferior to that of potassa, soda, or ammonia. Its solution attracts carbonic acid speedily from the air, and an insoluble carbonate is precipitated ; carbonic acid water and alkaline carbonates produce the same effect. It turns the blue infusion of cabbage green, and renders turmeric paper brown. All its salts, with the exception of the sulphate, are poisonous.

915. The most delicate test of baryta is sulphuric acid, which gives a copious precipitate, whenever it is dropped into a solution of baryta or of any of its salts ; solutions of sulphates produce the same effect. Sulphate of baryta is precipitated in all these cases, in the form of a fine white powder. The precipitate is easily distinguished from sulphate of lime, as water in which it has been digested gives no precipitate with a solution of hydrochlorate of baryta ; whereas, if the precipitate thrown down had been sulphate of lime, a portion of this salt would have been dissolved, and on adding hydrochlorate of baryta, the baryta would have combined with its sulphuric acid, and been precipitated. It must be recollected also, that lime water gives no precipitate with sulphuric acid, while barytic water gives a copious precipitate.

916. BINOXIDE of BARIUM is prepared by transmitting oxygen gas over baryta at a red-heat as long as it continues to absorb any. It has also been formed by heating carefully baryta with the chlorate of potassa, the baryta absorbing oxygen from the chlorate and leaving chloride of potassium, which is removed by cold water.

917. NITRATE of BARYTA is prepared by adding nitric acid to a solution of the hydrosulphate of baryta, till it ceases to produce any effervescence, or till neutralization is indicated by the vegetable blue, evaporating· it after it has been filtered, till a pellicle appears on its surface. Hydrosulphuric acid is disengaged, and a considerable portion of it is decomposed by the nitric acid; a copious precipitation of sulphur taking place (328). By digesting the native or artificial carbonate of baryta in nitric acid· diluted with 8 or 10 parts of water, the same compound is obtained, and carbonic acid is disengaged with effervescence. This salt crystallizes in octohedrons, which contain no water of crystallization, and are soluble in about 11 parts of cold and in 3 of boiling water. It is used in the preparation of baryta, and in producing one of the varieties of the green-light mixture, which is usually composed of the following ingredients :

Nitrate of Baryta,	.	.	.	770
Sulphur,	.	.	.	130
Chlorate of Potassa,	.	.	.	50
Charcoal,	.	.	.	30
Metallic Arsenic,	.	.	.	20

918. SULPHATE of BARYTA, or HEAVY SPAR, exists in considerable quantity in nature, and is formed artificially when sulphuric acid and baryta are presented to each other in solution ; it is very insoluble in water. From it, baryta and its other compounds are usually prepared. It is converted in the first place into sulphuret of barium, by decomposing it with charcoal (in the same manner as in the preparation of sulphuret of potassium), and then into hydrosulphate of baryta, by digesting it in water. The native sulphate should be exposed to a full red-heat and then quenched in cold water, that it may be easily reduced to a fine powder ; it is then mixed with a fifth part of its weight of powdered charcoal, and the mixture is made into a tough mass with a little oil, and exposed to a strong red-heat for two hours in a furnace. The mass that remains consists almost entirely of sulphuret of barium, with a little undecomposed sulphate of baryta. By digestion in water, the sulphuret of barium is dissolved, and a solution of the hydrosulphate of baryta obtained, the sulphuret reacting on part of the water in the manner described in 784. If a strong solution of the

hydrosulphate be made, crystals will be deposited as it cools ; it is very soluble in water.

919. Carbonate of Baryta is very insoluble, like the other earthy carbonates, and effervesces with the stronger acids. It exists native (Witherite) ; but, when required in a minute state of division, it is usually prepared by adding a solution of an alkaline carbonate to a solution of the hydrosulphate, or of any other soluble salt of baryta. The carbonic acid of the carbonate unites with the baryta, while the acid previously combined with it goes to the alkali, and forms a salt which remains in solution.

920. Hydrochlorate (Muriate) of Baryta may be prepared in the same manner as the nitrate. When the carbonate of baryta is employed, the hydrochloric acid may be diluted with five or six times its bulk of water, and the carbonate in fine powder added to it as long as any effervescence takes place, digesting it afterwards till the solution becomes quite neutral. It is much employed as a chemical test, chiefly to detect the presence of sulphuric acid. When evaporated to a pellicle and set aside to crystallize, tabular crystals are formed, composed of one equivalent of the hydrochlorate of baryta and one of water. They are soluble in two and a half parts of water at 60°, and about one and a fourth at 222°. When exposed to a red-heat they are converted into chloride of barium. Symb. $HCl + \cdot Ba = \cdot H \,\&\, ClBa$.

Sect. II.—Strontium.

Symb. Sr. *Eq. by W.* 43.8 ; *Resembles Barium, and is procured in a similar manner.*

Strontia.

Symb. OSr *or* ·Sr. *Eq. by W.* 51.8 (O.8 + 43.8 Sr).

921. This earth bears a great resemblance in all its leading chemical properties to baryta, and its compounds may be prepared in the same manner as those of baryta. It was discovered by Dr Hope. Strontia is generally prepared from the carbo-

nate, by reducing it to powder, mixing it with some charcoal, and exposing it in a crucible to an intense heat in a smith's forge.

922. Baryta and strontia are distinguished easily from each other, by their action on inflammable matter in a state of combustion. If a small crystal of the hydrochlorate or nitrate of strontia be put upon the wick of a burning candle, or if it be touched with a glass-rod which has been dipped into a solution of a salt of strontia, the flame immediately becomes of a rich red colour. Baryta and its salts communicate only a faint yellow colour with a tinge of green to flame, so that its action is in general scarcely perceptible. The red colour produced by strontia disappears when the salt becomes quite dry, but may be made to return by touching it with a rod dipped in water. Also, sulphate of strontia is more soluble than the sulphate of baryta, so that while baryta is completely precipitated by an alkaline sulphate, some sulphate of strontia would remain in solution, and give a precipitate with an alkaline carbonate.

923. The mixture for the red-light used for fireworks is composed principally of dry nitrate of strontia, which ought to be freed from any water of crystallization, of which it contains a large quantity, before it is mixed with the other ingredients. These are principally sulphur, charcoal, and nitre ; or, sulphur, sulphuret of antimony, and chlorate of potassa. The nitrate ought also to be carefully purified from any nitrate of iron, a very deliquescent salt ; this is easily effected while the nitrate is in solution, by adding a portion of caustic strontia till the liquid becomes slightly alkaline, any excess of strontia being removed afterwards by a stream of carbonic acid, which precipitates it in the form of carbonate of strontia.

When chlorate of potassa is used, it should be added after all the other ingredients have been thoroughly mingled and reduced to the finest powder, mixing it merely on paper. The following mixture has been much employed in making red-light, being easily prepared ; the smoke presents a purplish tint.

Nitrate of Strontia,	.	.	.	.	400
Sulphur,	.	.	.	.	130
Charcoal	.	.	.	.	0
Sulphuret of Antimony,	.	.	.	40
Chlorate of Potassa,	.	.	.	.	50

CHAP. III.—MAGNESIUM.

Symb. Mg. *Eq. by W.* 12.7.

924. MAGNESIUM is the metallic base of magnesia, the most important of its compounds. Magnesium has been obtained only in very small quantities, and by the same process as calcium and barium, to which it bears a considerable resemblance. Bussy has prepared it, by passing potassium in vapour over the chloride of magnesium.

MAGNESIA.

Symb. OMg *or* ·Mg. *Eq. by W.* 20.7 (0.8 + 12.7 Mg).

925. To prepare magnesia, the carbonate is exposed to a red-heat in a covered crucible, for an hour or two ; when a small quantity is employed, as half an ounce or an ounce, the carbonic acid is completely expelled in half an hour, if the temperature be not allowed to decline. Magnesia may be obtained also, by adding a solution of caustic potassa or soda to a solution of any of its salts, the alkali uniting with the acid of the magnesian salt, and forming a compound which remains in solution, while the magnesia is precipitated. It must then be washed on a filter, by repeated affusions of water.

926. Throw a small quantity of magnesia into a glass containing sulphuric acid, diluted with three times its bulk of water. If it contain no carbonic acid, it will be completely dissolved without effervescence, on stirring the liquid with a glass rod.

927. Mix another portion of magnesia with an ounce or two of the blue infusion of cabbage ; it will be rendered green in the same manner as by a solution of an alkali or alkaline earth. Water with which magnesia has been shaken does not produce this effect, very little being dissolved, as magnesia requires a large quantity of water for its solution. Upwards of 5000 parts

are necessary, according to Dr Fyfe, to dissolve one of magnesia at natural temperatures.

928. Magnesia is easily distinguished from the preceding earths, by forming a very soluble compound with sulphuric acid (sulphate of magnesia), and by its comparative insolubility in water. Its salts likewise give no precipitate, when in solution, with the common carbonate of ammonia, but, on adding a little phosphoric acid or phosphate of soda, a copious white precipitate, composed of phosphoric acid, ammonia, and magnesia, is thrown down. Its salts, when diluted, give no precipitate with oxalate of ammonia.

929. SULPHATE OF MAGNESIA, or EPSOM SALT, may be prepared by adding carbonate of magnesia to sulphuric acid diluted with four parts of water, till it is completely neutralized, evaporating the solution afterwards till crystals are formed when a drop of the liquid is taken out on a glass-rod; it may then be set aside to crystallize. It is soluble in its own weight of cold water, and in ¾ths of its weight of boiling water.

930. On the large scale, it is prepared from bittern, the liquid that remains after most of the common salt has been obtained from sea-water by evaporation; it is boiled to separate an additional portion of common salt and part of the water, crystals of sulphate of magnesia being deposited as it cools, which are purified by repeated crystallization. It is also prepared from magnesian limestone (a compound of carbonic acid, magnesia, and lime), a mineral that is found in large quantities in different parts of this country, by digesting the mineral in diluted sulphuric acid.

931. The sulphate of magnesia of commerce is sometimes mixed with a little hydrochlorate of magnesia, derived from the bittern from which it is prepared. It renders the salt deliquescent, and may be easily detected by pouring sulphuric acid on it, and holding over it a rod dipped in water of ammonia, hydrochloric acid being disengaged by the sulphuric acid, if any hydrochlorate be mixed with the salt, and forming white fumes with the ammoniacal gas arising from the water of ammonia.

932. CARBONATE OF MAGNESIA, called also SUBCARBONATE OF MAGNESIA, is prepared by decomposing sulphate or hydrochlorate of magnesia by carbonate of potassa or soda. The carbo-

nate of soda is more frequently used than the former, as it is usually obtained in a purer state; 143.62 grains of the crystallized carbonate of soda decompose 123.8 of the crystallized sulphate of magnesia. The salts must be dissolved separately in five or six times their weight of boiling water.

933. In this process, the carbonic acid of the carbonate unites with the magnesia of the sulphate, forming the carbonate that is precipitated, the sulphuric acid combining with the soda and remaining in solution. The mixture should be boiled for a short time before it is allowed to cool, and the bulky precipitate of the carbonate is to be washed with pure water, to remove any adhering sulphate, spreading it on a linen filter.

934. The BICARBONATE of MAGNESIA is prepared by transmitting a stream of carbonic acid through carbonate of magnesia suspended in water; it is soluble in about 50 parts of water, and the solution is known in commerce by the name of *Aerated Magnesia Water.*

935. To prepare a small quantity of this liquid, put some carbonate of magnesia in fine powder into a bottle, and fill it nearly two-thirds full of carbonic acid water. On shaking them together for some time, and filtering the liquid, it will be found to contain bicarbonate of magnesia in solution.

936. Expose part of the solution to heat till the excess of carbonic acid is expelled; the liquid will become quite turbid, the carbonate being again deposited.

937. HYDROCHLORATE OF MAGNESIA (chloride of magnesium when perfectly dry) is extremely deliquescent. It exists in some saline springs, in sea-water, and very largely in the liquid that remains after sulphate of magnesia has been extracted from bittern (930).

CHAP. IV.—ALUMINUM.

Symb. Al. *Eq. by W.* 13.7.

938. ALUMINUM has been prepared by Wohler, whose process is described in Brewster's Journal, vol. ix. p. 117–18. It burns when exposed to a red-heat in contact with air, and

becomes alumina. At natural temperatures, it does not readily oxidize in air or water.

ALUMINA—*(Sesquioxide of Aluminum).*

Symb. O^3Al^2, *or* $:Al^2$.   *Eq. by W.* 51.4 ($O.24 + 27.4$ Al).

939. Alumina is procured by adding an excess of carbonate of potassa to a solution of *alum* (a compound of sulphuric acid, potassa, and alumina). The precipitate is *hydrate of alumina*. It is to be well washed with hot water, redissolved in diluted hydrochloric acid, and again precipitated by ammonia or carbonate of ammonia. It is to be washed again and dried. Then, on exposing it to a full red-heat, the water is expelled, and dry alumina remains.

940. By another process, pointed out by Guy-Lussac, it may be procured more easily. *Ammonia-alum* (sulphate of alumina and ammonia) is heated to a full red-heat, by which the water of crystallization, and the ammonia and sulphuric acid, are dissipated, and alumina remains.

941. By simply adding ammonia to solution of alum, the greater part of the alumina is precipitated, still mixed, however, with sulphate (or sub-sulphate) of alumina and sulphate of potassa.

942. Alumina is destitute of taste or smell, colourless, insoluble, and does not affect the vegetable blues. It has a great attraction for water, which it quickly absorbs from the air, in considerable quantity. It is distinguished by its cohesiveness and plasticity, from which it is the basis of those earthy compounds or clays employed for manufacturing porcelain, pottery-ware, &c. It is also much employed as a mordant in dyeing and calico-printing, having an affinity both for fibre of cloth and organic colouring matters, by which it binds them to each other, or *fixes* colours.

943. Boil a little of the precipitated alumina in an ounce or two of a solution of caustic potassa till it is dissolved. If the alumina be pure, it will be completely dissolved, a character which distinguishes alumina from the preceding earths. Alumina is precipitated from its salts by ammonia and the alkaline carbonates; and also by soda or potassa, either of the latter redissolving the precipitate when added in excess.

944. SULPHATE OF ALUMINA AND POTASSA, or ALUM. This, the most important compound of alumina, is largely manufactured in this country. Alum-slate, containing much aluminous earth and sulphuret of iron, is roasted, by which the latter compound is oxidized ; and on lixiviation, sulphates of alumina and of iron are procured. The latter is separated by evaporation and crystallizing ; and a salt of potassa (hydrochlorate or sulphate) being then added to the solution, sulphate of alumina and potassa is formed, which is procured crystallized in octohedrons.

945. Alum has an acid and astringent taste, with a slight degree of sweetness. It is soluble in five parts of water at 60°, and in a little more than its own weight of boiling water. It reddens litmus. Its crystals contain nearly half their weight of water of crystallization. Alum is decomposed by alkalis and alkaline carbonates, and other salts which give insoluble precipitates with sulphuric acid. By a red or white heat, all its acid is expelled.

946. Alum generally contains a small quantity of peroxide of iron. This may be separated by repeated crystallization. The alum manufactured at Tolfa in 'Italy, is said to be free from this impurity.

947. The Alumen Exsiccatum or Ustum of the different Colleges is merely alum deprived of its water of crystallization by exposure to heat. A small quantity may be easily prepared by placing an ounce of alum in an iron cup, and heating it over a chauffer. The heat must be continued till it ceases to boil and has become quite solid, when it is obtained in the form of a light, friable, spongy mass.

948. SODA-ALUM, AMMONIA-ALUM, and other varieties of alum, may be prepared by substituting a salt of soda, or ammonia, as it may be, for the salt of potassa used in preparing the common alum. Also, an *Iron-alum* may be made, in which peroxide of iron replaces the alumina, using a sulphate of the peroxide of iron in place of sulphate of alumina.

949. A PYROPHORUS is easily prepared, by mixing alum with sugar and exposing it to heat. Different proportions have been recommended ; three of alum to one of sugar do very well. Two or three ounces of the mixture should be taken and melted in the first place over an open fire in an iron ladle, continuing the heat till most of the water of crystallization which the alum con-

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tains shall have been expelled, and the mass have assumed such a consistence, that it may be easily reduced to powder ; it must be stirred constantly the whole of the time with an iron rod or spatula,' and prevented from adhering to the sides of the iron ladle. It is then reduced to powder, and exposed to a red heat in a small iron bottle or tube-retort, till the gas which is disengaged begins to burn with a pale blue flame, a short time after which, it is to be removed from the fire, and the mouth of the vessel plugged up with a little well worked clay till it becomes cold, replacing it then with a cork, and making it air-tight with gas lute.

950. This substance inflames in atmospheric air at natural temperatures, and burns brilliantly in oxygen. Small quantities should be used at a time, and the cork of the iron bottle ought to be replaced, whenever as much as may be required is taken out, as it is soon destroyed by exposure to the air. During its preparation, part of the carbonaceous matter of the sugar decomposes the sulphuric acid, the potassa, and the alumina, so that the product may be regarded as a sulphuret of aluminum and potassium, mixed with the remainder of the carbon of the sugar. Some are inclined to believe that a small quantity of potassium is set free, and that its inflammable properties depend more upon this, than upon the minute state of division in which the carbon is obtained ; but the sulphuret of potassium is generally believed to be the active ingredient.

CHAP. V.—SILICUM.

Symb. Si. *Eq. by W.* 22.

951. This body is sometimes classed among the non-metallic elements, to some of which, as boron, sulphur, it bears a considerable resemblance in its general chemical relations ; while, being destitute of the characteristic metallic lustre, and a non-conductor of electricity, it differs considerably from the metals. Berzelius prepares it by the action of heat upon a mixture of potassium with the fluoride of silicum and potassium. It is a dark solid, of a brownish colour, incombustible, and not easily

oxidated, except by deflagration with the carbonate of potassa or soda, when it becomes silica, and remains in union with the alkali.

SILICA; *(Oxide of Silicum, Silicic Acid, or Siliceous Earth.)*

Symb. OSi, *or* ·Si. , *Eq. by W.* 46 (O.24 + 22 Si).

952. This earth is the most abundant compound in nature, sandstone, flint, and quartz, consisting almost entirely of silica, while it enters largely into the composition of most other rocks and minerals. It is hard, tasteless, perfectly insoluble in water, except when presented to it in the nascent state, and unaltered by heat under that of the oxyhydrogen blowpipe, by which it is fused. When separated from a solution of some of its compounds, it appears as a gelatinous hydrate. It is now generally considered to resemble an acid in its chemical relations; and its compounds with the alkalis are accordingly termed *silicates.*

953. The purest silica is procured by exposing transparent and colourless rock-crystal to a red heat, and throwing it in that state into cold water, that it may be easily reduced to powder. Flint or common quartz, similarly treated, gives a nearly pure silica. The silica which is precipitated when fluosilicic gas is passed into water (692) is extremely pure; and the silica procured, as described in par. 954, is very nearly pure, presenting only a very slight trace of alkali. For ordinary experiments with this substance, purified Lynn sand may be employed, which can be obtained from most flint-glass manufactories. •

954. Combined with a certain proportion of fixed alkali, silica becomes soluble. Separated by an acid from its combination with an alkali, the silica remains in solution if the liquid be very dilute, water dissolving it in the nascent state. If the solution be evaporated to dryness, the silica becomes perfectly insoluble; the salt mixed with it may be removed by lixiviation, and on exposing the hydrate of silica remaining to a red heat, the water is entirely expelled.

955. GLASS is the most important compound of silica, and is prepared by fusing it along with a fixed alkali. This compound varies very much in its properties according to the purity of the

materials employed, and the proportions in which they are mixed.
Other substances also are added, to improve its quality, and render it fit for a variety of purposes to which it is otherwise inapplicable ; thus, a small quantity of the binoxide of manganese removes the green tint which it otherwise usually presents; the oxide of lead renders it more fusible, and improves its lustre ; and nitre removes any carbonaceous impurities.

956. Fuse three parts of Lynn sand (purified previously by washing it with water and exposing it to a red heat) with one part of purified carbonate of potassa in a crucible, placing it in a furnace so that it may be exposed to a very strong heat.   A transparent brittle glass is obtained, quite insoluble in water, and having usually a greenish tinge, derived from a minute portion of iron in the materials or in the crucible.   The sand and the carbonate should be well mixed together, and the crucible should not be more than a third full, placing it on a piece of brick so as to rest an inch and a half above the branders of the furnace ; a cover should also be placed loosely over it.   The glass is formed by the silica of the sand uniting with the potassa, the carbonic acid being disengaged.   About 800 or 1600 grains of materials give a very good specimen of glass.

957. Fuse another portion of the same materials with one or two grains of the binoxide of manganese.   The glass will be found to have acquired a light tinge of purple, and to be free from the green or greenish-yellow tinge which the iron communicates.   When glass becomes purple from too much manganese being employed, the purple tint is removed by thrusting a stick of wood into the pot with the fused glass, the manganese being deprived of part of its oxygen by the carbon.

958. In another crucible, fuse three parts of the carbonate of potassa with six of the red oxide of lead and ten of sand.   The mixture melts at a much lower temperature than the former, and the glass formed is of the same nature as the flint-glass prepared at the different glass-works.   The same materials, with the addition of a small quantity of manganese, give a rich purple-coloured glass, and with the oxide of cobalt, it may be obtained of a fine blue colour.   See par. 967.

959. Fuse one part of sand with three of the carbonate of potassa, and pour the liquid on an iron plate after all effervescence has ceased.   The compound procured in this manner has the

same appearance as glass, but it deliquesces speedily on exposure to the air. It is usually called SILICATED POTASSA. In this case all the carbonic acid of the alkali is not expelled, and its solution effervesces on the addition of acids. It must be kept in close vessels. It is soluble in water, forming the *liquor silicum*.

960. Add some sulphuric or hydrochloric acid to a solution of silicated potassa; the acid unites with the alkali, and the silica is precipitated as a hydrate, in combination with a part of the water. When the solution is very dilute, the silica, though separated from the alkali, is not precipitated (954).

961. Add a solution of the hydrochlorate of ammonia to a solution of the silicated potassa; the hydrochloric acid combines with the potassa, and the whole of the silica is precipitated, and is not in this case liable to be redissolved. (Faraday.)

962. A variety of soap, called FLINT-SOAP, has lately been prepared, containing silicated soda in addition to the usual ingredients. This is considered to improve the detergent property of the soap, and is said to render it capable of mixing with salt water, so that it might be employed for washing at sea.

963. The materials used for the various kinds of glass are as follows: The proportions vary somewhat in different works.

COMMON BOTTLE GLASS.

Common Sand, ...	100
Kelp (or soap-makers' waste), . .	30
Lixiviated earth of wood-ashes, . .	160
Fresh wood-ashes, ...	30
Brick-clay, ...	80
Fragments of Glass, . . .	100

CROWN OR WINDOW GLASS.

Soda (carbonate), ...	200
Fine Sand, ...	300
Lime, ...	33
Fragments of Glass, . . .	250

PLATE-GLASS.

Soda, ...	200
Fine Sand, ...	300
Lime, ...	30
Manganese, ...	2
Cobalt azure, ...	0.18
Fragments of fine glass, . . .	300

FLINT-GLASS.

Purified Pearl ash, ...	40
Fine Sand, ...	120
Litharge (oxide of lead), . . .	35
Nitre, ...	13
Manganese, a very little.	

964. The fine glass called *Flint-Glass*, was formerly prepared with ground flint (previously calcined) instead of sand, whence the name which it still retains. A fine white sand, procured from Lynn in Norfolk or Alum Bay in the Isle of Wight, is used for the finer kinds of glass. It is for flint-glass only that *oxide of lead* is used.

965. A specimen of flint-glass, analyzed by Dr Faraday, was found to contain—

Silica, ...	51.93
Oxide of Lead, ...	33.28
Potassa, ...	13.77

and a fractional part of alumina, and of the oxides of iron and manganese. The above proportions are nearly those of one eq. of oxide of lead, one of potassa, and four of silica, so that, considering the silica to perform the function of an acid, this glass might be regarded as a compound of bisilicate of lead and bisilicate of potassa.

966. Though flint-glass is quite insoluble in water in the state in which it is usually obtained, it may be dissolved in small quantities, if reduced to a very fine powder, and it then communicates a green colour to the blue infusion of cabbage. In specimens of glass, reduced to an impalpable powder at the glass-works here for analysis, test-paper was rendered green immediately, on rubbing it with a little of the glass and water.

967. Glass is coloured of various tints by metallic oxides. Iron gives a green, yellow, or brown, according to the degree of oxidation. Copper gives a green, or a red when partly deoxidated by mixture with tartar. Manganese gives various tints, from purple to black. Cobalt gives a fine blue. Antimony a yellow. Silver a yellow. Cobalt and antimony a green. Gold (the purple of cassius is used) communicates a rich ruby colour. Chrome gives green or red, according to the degree of oxidation.

In the above cases, the depth of the tint is in proportion to the quantity of colouring matter. ENAMEL is glass rendered white and opaque by oxide of tin. PASTE is formed from rock-crystal or fine sand, oxide of lead, potassa, and borax.

968. Berthier has remarked, that many mixtures of different salts are much more easily fused on exposure to heat, than either of the salts separately. Five parts of carbonate of potassa become so fusible, when mixed with four of carbonate of soda, that the mixture is rendered quite fluid, when heated in a small crucible. When a little siliceous matter is thrown into this fluid, carbonic acid is rapidly disengaged with effervescence, and a vitreous compound is obtained. Berthier has proposed to use this mixture for fusing siliceous minerals to prepare them for analysis.

969. A platinum crucible is constantly employed in the examination of siliceous compounds. One of the size shewn in the

Fig. 187.
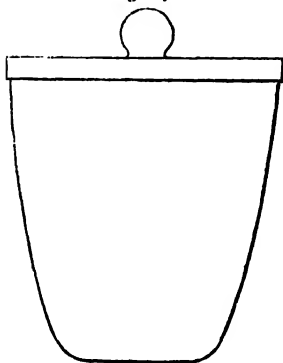
annexed figure (187) will be found well adapted for the greater number of purposes to which it is applied; but much smaller crucibles are frequently used. It should not be more than a third full, with materials that have any tendency to effervescence. In heating it, a charcoal fire alone should be used, or gaseous inflammable matter, as a mixture of gas and air; when heated in contact with cinders, a portion of slag or fused ashes often adheres to the side, by which it is much injured; and cannot then be treated freely with acids in extracting materials heated in it. But for all ordinary purposes, the spirit of wine lamp is preferred, from the facility with which it is made to evolve a steady and uniform heat, without, in any way, soiling the crucible. With a powerful spirit-lamp, having a hollow cylindrical wick, any elevation of temperature, such as may be required in analytical operations, may easily be obtained.

970. The platinum crucible, when warm, should never be touched with any tongs or pincers having the slightest coating of antimony, tin, or lead, as these metals combine with platinum at a high temperature, and form very fusible compounds.

971. In using the platinum crucible for the fusion of siliceous compounds, alkaline carbonates are usually employed. When caustic potassa is used, the platinum cruci-

Fig. 188.

ble is apt to be corroded. A silver crucible is accordingly employed where the siliceous compound requires the use of the caustic alkali.

972. A very convenient method of using the spirit of wine, where a high tempera- ture is required, has been introduced by Mr Trevelyan. It consists in expelling it from a small copper vessel or boiler, about four or five inches in diameter, the vapour being made to pass through an argand burner, such as is used for gas, and the crucible sus- pended above it, as in Fig. 188. The in- tensity of the flame is regulated by the power of the lamp with which the boiler is heated.
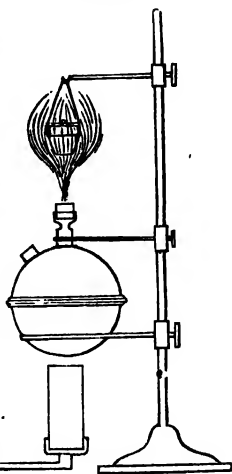
973. GLUCINUM, ITTRIUM, ZIRCONIUM, and THORINUM, are the metallic bases of the earths Glucina, Ittria, Zirconia, and Thorina. Glucina is found in the beryl and in the emerald ; Ittria was dis- covered by Gadolin in a mineral now called Gadolinite ; Zir- conia by Klaproth in the zircon of Ceylon ; and Thorina was discovered a short time ago by Berzelius (*Jameson's Journal*, October 1829). As none of these, however, are likely to be made the subject of experiment by beginners, it will be unneces- sary to say more of them in this place.

ORDER III.—CALCIGENOUS METALS.

I.—COMMON METALS WHOSE OXIDES CANNOT BE REDUCED BY HEAT ALONE.

CHAP. I.—IRON.

Symb. Fe. *Eq. by W.* 28. *Sp. gr.* 7.7 *Cast-iron is fused at 2786°; Pure iron (malleable iron) requires the highest heat of a smith's forge to melt it.*

974. IRON is procured by extracting it from its ores, earthy compounds which are very abundant, while *native iron* is very rare, few well authenticated specimens having been seen, except those of meteoric origin; and even these are rarely met with. Meteoric iron is generally *soft* and *malleable* (985), and contains a little nickel and cobalt.

975. The ores from which iron is procured are *oxides* or *carbonates* of iron. From its oxides, iron is extracted by heating it intensely in a blast furnace (979) along with charcoal. Iron of a superior quality is procured from the oxides, and wood charcoal is always employed to reduce them. In some English furnaces, the *peroxide* or *red oxide* (hæmatite) is employed. In the Swedish iron-works, from which a very fine quality of iron is procured, the *black oxide of iron*, or *magnetic iron ore*, is employed.

976. In this country, almost all the iron is procured from the CLAY IRON-ORE, an earthy compound containing varying proportions of iron, in the state of oxide (protoxide). It contains also a quantity of alumina, from which this ore derives its name, a little silica, and minute quantities of sulphuret of iron, manganese, &c. The following table represents the chemical composition of several kinds of clay iron-ore in use at the Clyde

Iron-Works near Glasgow, as given by Dr Colquhoun in Brewster's Edinburgh Journal, 1828.

Protoxide of Iron,	.	.	53.03	47.33	35.22
Carbonic Acid,	.	.	35.17	33.10	32.53
Silica,	.	.	1.40	6.63	9.56
Alumina,	.	.	0.63	4.30	5.34
Lime,	.	.	3.33	2.0	8.62
Magnesia,	.	.	1.77	2.2	5.19
Peroxide of Iron,	.	.	0.23	0.33	1.16
Bituminous Matter,	.	.	3.03	1.70	2.13
Sulphur,	.	.	0.0	0.22	0.62
Oxide of Manganese,	.	.	0.0	0.13	0.0
Moisture and Loss,	.	.	1.41	2.26	0.0
			100 +	100 +	100 +

The protoxide of iron contains 28 parts of iron and 8 of oxygen, or 7 of iron to 2 of oxygen. The carbonic acid may be in union partly with the protoxide of iron as carbonate of iron, partly with the lime as carbonate of lime. The two first are the most valuable iron-ores in the field in the west of Scotland. The third is the least valuable of that field that is worth working.

977. The first operation in the process for extracting metallic iron from the clay iron-ore, is *roasting it (or calcining it)*. The ore is spread out on the ground in beds, three or four feet high, and many feet long and broad, being mixed with alternate layers of coal or other inflammable matter. Sometimes there is so much carbonaceous matter in the ore, that little requires to be added. The mass is then set fire to and allowed to burn as long as it will, which is generally about a week or two. After being thus roasted, the ore is found to have diminished considerably in weight (from about 20 to 35 per cent). The carbonic acid has been expelled, and also any sulphur which the ore may contain. Part of the oxide has passed to the state of peroxide, as is shewn by the red colour, and the ore is rendered brittle, by which it is more ready to be broken down and act with the materials it meets in the furnace.

978. The roasted ore is then mixed with the proper proportions of charcoal, coke, or raw coal, and limestone, and put into the blast furnace. In some English iron-works, where the ore contains *lime*, and little *alumina*, clay or some compound containing alumina is substituted for limestone; and in some cases,

by mixing a *clay* iron-ore with a *lime* iron-ore, each kind of ore furnishes the ingredient necessary for reducing the other, and then the two ores with the carbonaceous matter alone are put into the furnace. In the same way, sand is added, if there be too little silica in the ore. The nature and proportions of the fluxes added must vary with the composition of the ore. In the Scotch furnaces, limestone is almost invariably employed.

979. The following figure (189) will give a general idea of

Fig. 189.
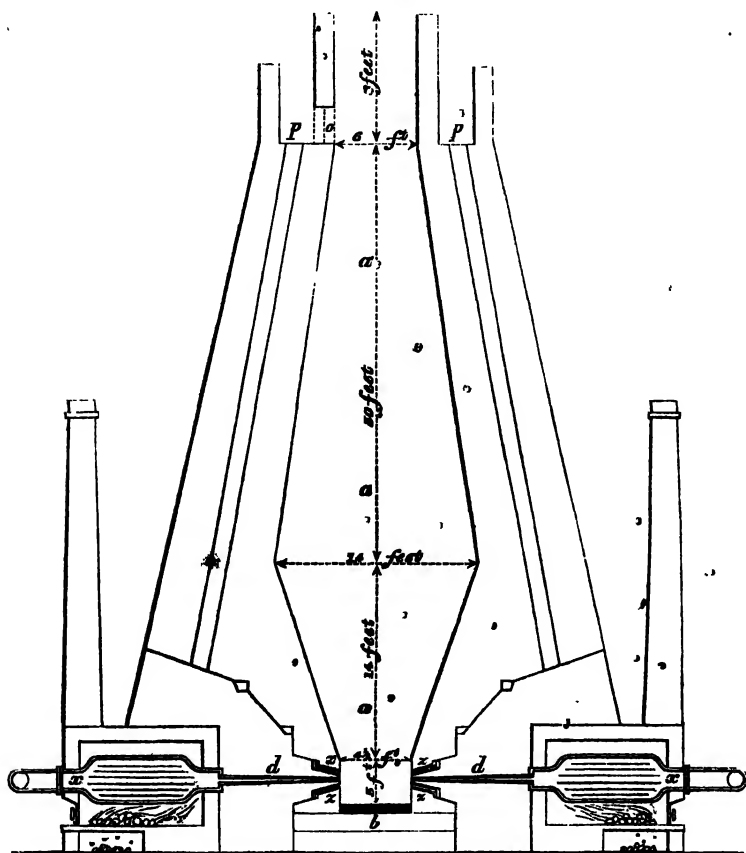
the construction of a BLAST FURNACE. It may be compared to an immense crucible, made of solid masonry, and lined interiorly

with successive layers of bricks made of the most infusible fire-clay. It is usually about 50 or 60 feet high, and its internal capacity may be about 5000 cubic feet. It somewhat resembles two cones of unequal size joined by their bases. The materials are put in at the top, and a pit or trough at the bottom receives the melted metal *b b*, which is run out into a bed of sand every eight or twelve hours, by tapping the furnace at the bottom. The fused earthy matters (called *slag* or *scoriæ*) that collect above the metallic iron, are run off more frequently, by an aperture higher up in the furnace.

980. A *blast furnace* differs from a common air furnace in being supplied with air for the combustion of the fuel by a pair of bellows, which pour in air more rapidly than it could enter by the draught arising from the external pressure on the column of heated air, and thus a more rapid combustion and more intense heat are procured. The *blast furnace* in which iron is prepared has no furnace-bars or branders, and the air is supplied and forced through the mass of fuel, ironstone, and limestone, by large and powerful bellows, worked by a steam-engine.

981. In Fig. 189, *d d* represent the pipes of the bellows, the extremities of which are called *tuyeres*, entering near the bottom of the furnace. There is frequently a space left between the fire-brick and stone-work, or between two layers of fire-brick, which is filled with charcoal or sand, the better to confine the heat. Sometimes the stone-work is dispensed with, the furnace being constructed solely of fire-brick, bound firmly by bars of iron all round. There is a gallery all round the top at *p* ; and the materials are raised there by machinery, and thrown in by a door at *e*. Immense volumes of flame rise out of the furnace top. The gases which give rise to these flames, the slag, and the metallic iron, are the products of the operation.

982. By the combustion of the coal, intense heat is produced, by which the cohesion of the particles is loosened, and thereby they are enabled to act upon each other, and the whole is fused, permitting the heavy metallic iron to fall through the liquid mass to the bottom. The hydrogen and carbon of the coal deoxidate the iron-ore, forming with its oxygen and with the oxygen of the air forced in, carbonic acid and watery vapour, which fly out at the top of the furnace. The lime of the limestone acts as a *flux*, uniting with the earthy matters of the ore and rendering

them fusible. The *slag*, which collects above the melted iron and is run out at an aperture above it, consists of the lime and earthy matters of the ore, united into a fusible compound, which soon cools and hardens into a semi-vitreous mass. Lime, though very infusible alone, is readily melted by heat when united with silica or alumina. The proportions of the different products vary in different works and with different kinds of ore. With one variety of ore in an English furnace, 36 tons' of materials gave 6 of pig-iron, about 16 of slag, and 14 tons were dissipated in the gaseous form at the top of the furnace.

983. A very great improvement, in an economical point of view at least, has lately been effected in the iron manufacture by the use of the Hot Blast. This consists in heating the air before it enters the furnace. This is done by causing the air to pass in contact with highly heated surfaces before it enters the pipe of the bellows. The pipes x x, Fig. 189, made of cast-iron, are heated by a small furnace to near a red heat, and the air passes through them before reaching the tuyeres. The air is heated by many varieties of apparatus, with the view of economizing the fuel. The hot air contributes to the development of the heat from the fuel the moment it enters the furnace; whereas the cold air, as it cannot support combustion till its temperature becomes considerably elevated, robs the materials of part of their caloric, and thus there is a much less intense heat than where the air has been previously raised to the necessary temperature. Accordingly, by the use of the hot air, the iron is extracted with the aid of a much smaller quantity of fuel than formerly. Also, it is used in the state of raw coal, not being previously formed into coke, as was done before the hot blast was introduced. It has been said that the iron procured in this manner is not possessed of the same strength and tenacity as that formed by the cold air; but from experiments lately instituted, there is reason to believe that there are no grounds for this opinion.

984. The iron thus produced is Pig-iron, or Cast-iron. It is not so tenacious as pure iron, and is rather brittle; but it possesses the valuable property of melting at a temperature procured with facility (2786°), by which it can be run into moulds, and thus made to assume any desired form. Cast-iron seems to owe its peculiar properties to the presence of a little carbon,

oxygen, and earthy matters, as some unreduced ore, mixed with it. It sometimes gives traces of phosphorus, sulphur, manganese and arsenic. Cast-iron varies considerably in its properties. Two principal varieties have been noticed, *white cast-iron* and *grey cast-iron*. White cast-iron is more hard and brittle than grey cast-iron, which is comparatively more soft and tough. This difference is considered to be owing more to the mode in which the particles are arranged, arising probably from differences in the rate of cooling, than to any difference in the chemical constitution. Iron may always be rendered hard by heating and quickly cooling, becoming at the same time, however, more brittle. The white cast-iron may be rendered tenacious like the grey, by heating and then cooling it slowly ; and the tough and soft grey cast-iron may be made to acquire the properties of the white cast-iron, by being heated and cooled quickly. Cast-iron resembles steel in its relation to heat. See paragraphs 987, 988, 989, 990.

985. MALLEABLE IRON, called also *Soft Iron*, *Wrought Iron*, *Forged Iron*, is a much purer iron, prepared from cast-iron. It is characterized by its extreme strength or tenacity, in which it is very superior to cast-iron. It is nearly infusible, being melted only by the highest heat of a smith's forge ; but when at a high temperature, it softens, and may then be beat into any required shape, or united firmly to another piece of iron by hammering, an operation termed *welding*. It is not perfectly pure, still containing a little carbon (about 0.5 per cent) and a minute portion of silicum.

986. The manufacture of malleable iron is carried on to a great extent in this country. Formerly iron was prepared from the ore in the malleable state by one operation. This process consists at present of three principal operations, *refining*, *puddling*, and *forging* or *hammering*. In the *refining*, the cast-iron is melted, in contact with coke, and kept fused for nearly a day. By this, the greater part of the carbon is burned off, and the earthy matters, as unreduced ore, rise to the surface, and are separated. In the *puddling* furnace (a reverberatory furnace), the iron is then melted, and frequently stirred with an iron-rod, while the flame plays over its surface, by which the carbon is more completely separated ; and it soon thickens and begins to grow stiff, even though the temperature be kept up. It is then

becoming malleable iron, and is divided into pieces of the neces-
sary size by the puddler ; and taken while still soft to the *forge*,
where it is hammered. It is then, along with other pieces,
heated, welded to them by hammering, and in powerful rollers,
formed into bars or rods, as may be desired.

987. STEEL is a compound of iron and carbon. It is prepar-
ed by exposing powdered charcoal and bars of the finest malle-
able iron in alternate layers, to a steady heat in a furnace for.
several days. This operation is termed *cementation*. The ma-
terials are closely packed in pots, which are then covered to ex-
clude the air and prevent the combustion of the charcoal. Sand
or earth is employed to protect the charcoal from the air. The
iron combines with about 1-100th or 1-150th of its weight of
carbon, becomes blistered on the surface, and it is now *steel*,
characterized by its extreme hardness, so as to be fit for being
formed into a fine point, or sharp edge. *Blistered* steel is a
good deal used ; but it is more customary to subject steel to an-
other process before using it. This consists in welding several
pieces, by heating them together and hammering them into
small bars ; this repeated several times, gives *hammered steel*, the
form of steel now most in use. The Swedish iron is always
preferred for the manufacture of steel. By continuing the pro-
cess of cementation longer or shorter, the iron may be more or
less carbonized, and rendered steel through and through, or only
at the surface,—to different depths, according to the purpose
for which it is required (see par. 988). Steel requires a higher
temperature than cast-iron to fuse it, but is much easier melted
than malleable iron. It then forms *cast-steel*, now so much em-
ployed.

988. CASE HARDENING is an operation performed on iron,
which communicates to the external surface the peculiar proper-
ties of steel, while the interior may still retain the strength and
tenacity of malleable iron. This consists in heating the bar of
iron in a box with carbonaceous matters for a short time, by
which the outer film becomes carbonized, and thus acquires the
hardness, &c. of steel. Bones, old leather, or prussiate of potash,
may be employed to give the carbon. The steel thus formed
may be restored to the state of soft iron again, by keeping it
at a red heat for several days in a box along with oxide of iron
or rusty iron filings. These abstract the carbon.

989. Expose a piece of soft steel to a bright red heat, and plunge it suddenly into cold water. It becomes so exceedingly hard, as scarcely to be affected by a file, and loses its toughness and elasticity, being now comparatively brittle.

990. Expose a piece of hard steel to a temperature between 400° and 600°, by placing it in hot oil or melted pewter; it regains its toughness and elasticity, and, by varying the temperature, it acquires various degrees of hardness, so as to be fit for the different purposes to which it is applied. It is in this manner that steel is *tempered*. Instead of using hot oil and a thermometer to regulate the temperature to which it is exposed, it is often heated in the open air, judging of the temperature by the colour it presents, as it then assumes a variety of tints, from a very faint yellow to a dark blue, according to the degree of the heat. These shades are produced by a little oxide of iron, being formed on its surface, and gradually increasing in quantity as the temperature rises. Instead of plunging a piece of hard steel into hot oil, it may be held over a spirit-lamp, till all the different tints have been produced.

991. Put a drop of nitric or hydrochloric acid on steel, and wash it afterwards with water. A black spot remains on the surface, the acid acting on the iron, while the carbon remains. The same appearance is presented with cast-iron, which contains still more carbon then steel; but forged iron, containing no carbon (or at least only a very minute quantity), still presents a bright metallic surface after it has been acted on by an acid. Steel contains from 1–120th to 1–50th of carbon; cast-iron from 1–25th to 1–15th. Hence, when cast-iron is used for preparing hydrogen, a smaller quantity will be procured than when forged iron is employed.

992. To procure pure iron for chemical experiments, filings of malleable iron are mixed with about one-fourth of their weight of oxide of iron, and fused in a hessian crucible, placed in a small blast furnace, and closed to exclude the air. The mixture also should be covered by a little powdered glass containing no lead. The carbon is thus removed, and pure iron remains. By heating oxide of iron to redness in a porcelain tube and passing hydrogen gas over it, the oxygen is removed by the hydrogen, and a very pure iron remains. Oxide of iron may be decomposed by hydrogen at a heat below redness, when, the metallic iron which

is separated, not being sufficiently heated to enable its particles to unite into a compact mass, remains in a spongy or porous state, and then has the property of inflaming spontaneously, when brought in contact with air.

993. In preparing a specimen of metallic iron from the clay iron-ore on the small scale in a crucible, 100 or 200 grains of the roasted ore may be employed, having reduced it previously to the finest powder. Should the raw ore have been obtained, it may be roasted previously by heating it in a crucible to redness for an hour or two. The ore is then mixed with limestone and charcoal in the finest powder, and placed in a crucible, of which

Fig. 190.

it should not fill more than a third or a fourth part. The crucible may then be put in the furnace, Fig. 133, page 151, placing it and luting it as shewn in Fig. 190. It must then be covered with fuel, the furnace being filled with it, and a white-heat maintained for two hours, unless it should be very intense, when one hour will be sufficient.
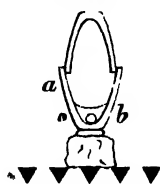
994. A blast furnace is often made on the small scale by inclosing a vessel c c (see Fig. 191) made of the best fire-clay, and lined externally with sheet-iron, in a second iron vessel d d d d,

Fig. 192.
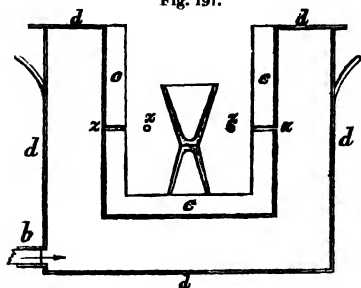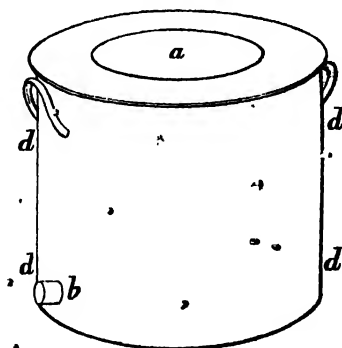
Fig. 191.

made to fit air-tight around it. The nozzle of a pair of bellows is fixed in at b, and air impelled when the fire has been kindled. An intense heat is produced as the air enters through the apertures z z z z. Fig. 192 gives another view of this fur-

nace. Coke or coal may be employed in this operation ; the for-
mer is preferred.

995. In this process, it is not always easy to adjust the pro-
portions of the flux and charcoal so as to procure a button of
metal at the first operation ; repeated trials are often necessary.
If the charcoal be not consumed, less must be used ; if the
materials do not run into a slag so as to allow the iron to sepa-
rate, more or less lime must be used, or some pounded glass or
fused borax may be added along with the lime. The following
table shews the results obtained in several mixtures containing
the same quantity of the same clay iron-ore, and illustrates the
proportions to be employed.

Roasted Ore,	200	200	200	200	200	200
Charcoal,	30	30	25	30	40	45
Limestone,	50	60	70	20	20	20
Borax (fused),	20	20	20	20	20	20
Glass,	0	0	0	20	20	20
Gave of Metallic Iron,	80	96	55	85	120	76

When the process is successful, the iron is found as a button,
imbedded in the centre of the glass as in Fig. 190. The crucible
should be carefully covered and luted, a small aperture being
left for the escape of gas. It should also be fixed to its support
with a little lute. Hessian crucibles are required in this ope-
ration.

996. Iron has a considerable attraction for oxygen. At ordi-
nary temperatures, indeed, it is not oxidated in air destitute
of watery vapour, nor in water free from absorbed air or oxygen.
But in a moist atmosphere, or in water freely exposed and im-
pregnated with air, iron soon attracts oxygen and rusts. Besides
oxygen, it absorbs carbonic acid, and forms carbonate of the
oxide of iron. But the oxide of iron soon attracts more oxygen
and water, while the carbonic acid is separated, and the ordi-
nary brownish rust of iron appears, a *hydrate of the peroxide of
iron*. This is said to contain also a little ammonia. When
burned in oxygen gas, or exposed to a red-heat in the open
air or in contact with water, iron is rapidly oxidated, hydrogen
being evolved in the latter case. The iron is converted into a

brittle scaly matter, the *black oxide* of iron (1010), containing different proportions of oxygen from the oxide or peroxide, and also varying in its composition under different circumstances in its formation. Iron is quickly acted on and dissolved by the sulphuric, nitric, and hydrochloric acids when a little diluted. Digested in acetic acid, it is more slowly oxidated, but is in time dissolved. In all these cases, salts of iron remain in solution. Most of the salts it forms with the non-metallic elements are soluble, excepting the carbonate.

.997. For ordinary experiments with iron, a quantity of iron-filings, wire, or turnings should be procured, which will be found much more convenient than large masses of metal.

998. Put a quantity of iron-filings into a plate, and moisten them with water from time to time as they become dry ; the iron is oxidated and soon passes into the state of hydrated peroxide (996).

999. Throw some iron-filings into the flame of a lamp or candle, or of any combustible matter, as the flame from a gas jet. The filings combine with the oxygen of the air, taking fire, and burning with brilliant scintillations.

1000. Heat one end of an iron bar to a bright white-heat, place it at the nozzle of a pair of bellows, such as is used at a smith's forge, and impel the air upon it. The iron burns, notwithstanding the constant impulse of the cold air, and black oxide of iron is formed in scales, which are blown away as they are produced.

1001. Procure a quantity of thin iron-wire ; about 12 or 20 pieces of common harpsichord wire, each 20 or 30 inches long, will do very well. Twist them together, and coil them round a piece of wood, an iron-tube, or the neck of a retort. Fix one

Fig. 193.

end of the coil into a cork, made to fit a wide glass jar of the form represented in the adjoining figure. Tie a little thread round the other extremity, and dip it into melted sulphur ; a small portion adheres to the thread. Melt this by holding it over a candle, taking care not to allow it to take fire, and blowing out the flame immediately, if it should. By dipping it again in the sulphur, and melting as before what adheres the second time, the thread acquires a sufficient coating of sulphur.
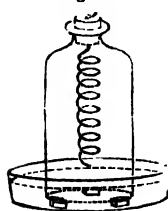
If the sulphur be then kindled, and the wire be introduced in this state into a jar full of oxygen, the heat produced by the rapid combustion of the sulphur is sufficient to inflame the iron, which then continues to burn brilliantly, and gives out a number of sparks.

1002. The jar containing the oxygen may be from four to six inches in diameter, and from ten to fourteen long, open below, and provided with a cork or stopple, fitting accurately to the opening above. When the cork is put in, the jar may be inverted full of water on the shelf of the pneumatic trough, and filled with oxygen in the usual manner. It is then removed on a tray to a shallow iron basin filled with water (or an earthen basin with some sand at the bottom does equally well), supporting it directly by two or three small pieces of brick or tile, to prevent the globules of melted oxide of iron, that are produced during the combustion, breaking the jar, if they should run to the side when they have fallen under the water. When every thing has been adjusted, the cork is taken out, and the sulphur at the end of the iron-wire is inflamed, introducing it steadily, and pressing the cork tightly into its place. As the combustion proceeds, the pressure of the air forces the water in the basin (which must be always kept full) into the jar, to supply the place of the oxygen as it is consumed.

1003. Much thicker wire than what is used for harpsichords may be made to burn in oxygen gas; and indeed, if the extremity of a thick rod or bar of iron be heated to whiteness in a furnace, and put immediately into a large vessel full of oxygen, it will burn in the same manner as the thin iron-wire.

1004. Oxide (or Protoxide) of Iron (Symb. OF or ·F. Eq. by W. 3C, = Oxyg. 8 + 28 Iron) is not easily procured in a pure state, from the great affinity which it has for oxygen, and the facility with which, when moistened, it attracts an additional portion of this element, even from atmospheric air. It is precipitated in combination with water (as a hydrate) when an alkali is added to a solution of its salts, appearing white at first, but gradually absorbing more oxygen and becoming the brownish-red peroxide. It is the compound formed when iron is dissolved in dilute sulphuric acid, remaining in union with the acid.

1005. Add a solution of potassa or soda to a solution of the sulphate of iron; if it contain no peroxide, a precipitate of a

white or greenish-white colour is thrown down, a compound of the oxide of iron and water. It soon becomes of a deeper green, however, and ultimately assumes a brown colour on exposure to the air, attracting an additional quantity of oxygen.

1006. Add, in the same manner, solutions of ammonia, lime, and baryta to separate portions of the sulphate of iron. Oxide of iron is precipitated as in the preceding experiment. The sulphates of ammonia and lime are left in solution, but the sulphate of baryta falls with the oxide of iron.

1007. PEROXIDE OF IRON, called also *sesquioxide* or *terdinoxide* of iron (Symb. O^3F^2 or $\vdots F^2$; Eq. by W.* 80 (O.24 + 56 Fe). This is a natural production, known by the name of *red hæmatite*. It is also found in union with two equivalents of water, forming *brown hæmatite*. The common brown rust of iron consists almost entirely of this oxide and water.

1008. To prepare PEROXIDE OF IRON, a crucible may be filled with green sulphate of iron, and exposed to a good red-heat in a furnace or open fire for one or two hours, previously luting on a cover with a little clay, and leaving a small aperture for the escape of gaseous matter. The water of crystallization in the green sulphate is completely expelled with part of the sulphuric acid, the remainder of which is decomposed, communicating part of its oxygen to the oxide of iron, while sulphurous acid is disengaged. Two eqs. of the sulphate are required to produce one of this oxide, one of sulphurous acid and one of sulphuric acid being evolved as the peroxide is formed.

$2 (\vdots S \cdot Fe) = \vdots S \ \& \ \vdots S \ \& \ \vdots Fe^2.$
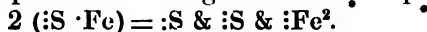
The peroxide of iron prepared in this manner, is of a red colour, very dark at first, but becoming of a lighter shade when it cools.

1009. The hydrated peroxide of iron may be procured by dissolving iron in a mixture of nitric and hydrochloric acids, and adding an alkali to the solution. The peroxide, in union with two equivalents of water, is precipitated.

1010. BLACK OXIDE OF IRON (Symb. $O^4 + Fe^3$, or $\vdots Fe^3$, or $OFe + O^3Fe^2$, or $\cdot Fe + \vdots Fe^2$; Eq. by W. 116 = O.32 + 84 Fe).

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* It is sometimes represented, however, by the number 40, and is said to consist of one equivalent of iron, and *one and a half of oxygen*, a mode of expressing its composition which has crept into general use, though it is certainly very incorrect.

This is the compound formed when iron is oxidated in the air or in contact with water at a high temperature. It is regarded as composed of the oxide and peroxide. But the oxide of iron formed when iron is oxidated in air at a red-heat, is found to vary in composition with the temperature and the time during which the oxidation is continued. This oxide is a native product, and is often termed the magnetic oxide of iron, or magnetic iron-ore.

1011. A number of tests have been proposed for detecting iron. One of the most delicate tests of iron in solution is the gall-nut, which produces a black colour with solutions containing a very minute quantity, even when no indication of the presence of iron has been obtained by using the infusion of galls ; the cause of this peculiarity has not been explained. All that is necessary in using the nut for this purpose is, to bruise it and throw it into the liquid under examination, part of which assumes a black or purplish colour in a day or two if any iron be present ; or, a slice of the nut may be suspended in it by a thread. The colour is produced by the tannin and gallic acid of the gall-nut, which are slowly dissolved by the water, combining with the oxide of iron. A deep tint is immediately produced, if there be a considerable quantity of iron in solution.

1012. When the quantity of iron in solution is very minute, and any carbonate of lime is present, the action of the galls is modified considerably. If the iron be in the state of oxide, the tint produced is deeper than usual ; but if the peroxide be present, the action of the galls is diminished, and the tint is very faint, or altogether absent.

1013. Pour a little of the infusion of galls into several glasses of water, to which different quantities of a solution of sulphate of iron have been added, that the different shades of colour which they present may be seen ; the precipitate is of a purple or black colour. It must be recollected, that all ordinary solutions of the sulphate of iron contain a portion of peroxide, and that it contributes essentially to the production of the dark tint. With a sulphate of the oxide, absolutely free from peroxide, no dark tint is induced ; and, even when it has been developed, it may be removed by deoxidating agents.

1014. The ferrocyanate of potassa is another very delicate test of iron, throwing down a rich blue coloured precipitate,

when added to a solution of a salt of iron in which the metal is in a high state of oxidation. Care must be taken in applying this test, that no excess of acid be present, which might produce a blue by decomposing the ferrocyanate alone.

1015. With salts of the oxide of iron the ferrocyanate gives a white precipitate, and when the solution contains both oxide and peroxide of iron, which is generally the case, the precipitate presents a variety of shades between a light and a deep blue, according to the proportion of the different oxides.

1016. If it be required to shew the pure white precipitate which the oxide gives with this test, the best method is to use a solution of the oxide of iron, made by shaking iron-filings in a small bottle nearly full of a solution of sulphurous acid in water ; the iron attracts a portion of oxygen from the sulphurous acid, and is dissolved without any effervescence.

1017. Instead of the common ferrocyanate of potassa, the red ferrocyanate, prepared by transmitting chlorine through a solution of the ferrocyanate, is frequently employed, being a much more delicate test of the presence of oxide of iron in solution ; it does not precipitate the peroxide, but with salts of the protoxide it gives at once a deep blue-coloured precipitate. Instead of preparing a portion of this new compound, it will be sufficient to add a portion of any solution containing free chlorine, along with the common ferrocyanate, to the salt of iron, the same effect being produced in this manner.

1018. Add a solution of the sulphocyanate of potassa to a concentrated solution of a salt of iron containing this metal in the form of peroxide ; it immediately becomes of a deep red colour.

1019. Add a few drops of a solution of the hydrosulphate of ammonia to a dilute solution of a salt of iron ; a copious black precipitate immediately appears, consisting of the sulphuret of iron. The oxygen of the oxide and the hydrogen of the acid produce water, the sulphuric acid and ammonia remaining in solution.

1020. Hydrosulphuric acid gas, when transmitted through a solution of a salt of oxide of iron, does not occasion any precipitate ; but when it is transmitted through a solution of a persalt, sulphur is precipitated, the hydrogen of the gas that is decomposed

uniting with part of the oxygen of the peroxide, and reducing it to the state of oxide.

1021. In examining a liquid with the view of detecting iron, any of this metal in the state of oxide may be easily converted into peroxide, by boiling it for a short time with a little nitric acid, or adding a little of the solution of chloride of lime.

1022. Succinate or benzoate of ammonia precipitates the peroxide of iron of a yellowish colour, but not the oxide.

1023. Add solutions of the pure alkalis to solutions of the persalts of iron, and compare the precipitates thrown down with those produced when salts of the oxide are used. The alkalis unite with the acids previously in combination with the oxide of iron, forming salts which remain in solution, while the latter is precipitated; if the carbonated alkalis have been employed, the oxide precipitated is combined with carbonic acid. When percarbonate of iron is precipitated it is soon decomposed (Soubeiran).

SALTS OF IRON, &c.

1024. NITRATE OF IRON may be obtained, by putting into a glass flask or bottle an ounce or two of iron-turnings, with an ounce of nitric acid previously mixed with seven or eight ounces of water. The iron is slowly oxidated and dissolved, and on concentrating the solution in the vacuum of an air-pump over sulphuric acid, green crystals of the nitrate may be obtained. They are deliquescent, and attract oxygen from the air.

1025. If the acid be not diluted with so much water, the iron attracts a larger quantity of oxygen, and the liquid acquires a reddish-brown colour, pernitrate of iron being formed, which does not crystallize on evaporating the liquid. In this compound 80 parts of the peroxide are associated with 162.6 of nitric acid, so that the term pernitrate does not express the relative proportions of acid and base. The same remark may be applied to all the terms usually applied to the more common salts of the peroxide of iron, as the persulphate, &c. They are often termed *Sesquiper*-salts, as an atom and a half of acid are united with an atom of peroxide, 40 being the number by which it is represented according to this view. See Note, page 293.

1026. When only a small quantity of water is added to the acid, and the iron is in a minute state of division, the action is very turbulent. Put three or four drachms of nitric acid into a glass, add two drachms of water, and throw into it 200 or 300 grains of iron-filings. Part of the acid is immediately decomposed, the iron is oxidated, combining with another portion of acid, and fumes are copiously disengaged, which must be carefully avoided, being composed principally of nitrous acid.

1027. The SULPHATE OF IRON is prepared in large quantities for use in the arts, by roasting the native bisulphuret of iron (iron-pyrites), and exposing it to air and moisture, the iron being converted into an oxide, and the sulphur into sulphuric acid, by attracting oxygen. On lixiviating and evaporating, crystals of this salt, known by the names of *copperass*, *green vitriol*, are procured. On the small scale, it may be prepared by mixing 6 parts of iron with 10 of sulphuric acid and 60 of water, evaporating the solution in a glass or earthen vessel, after the effervescence arising from the disengagement of hydrogen gas has ceased, and continuing the heat till a rod dipped into it presents appearances of crystallization, when taken out and held in the air. The solution may then be filtered, and green crystals of the sulphate will be formed as it cools. They consist of one equivalent of sulphuric acid, = 40.1, one of oxide, = 36, and seven of water, = 63 ; their equivalent, therefore, is 139.1. They are soluble in two parts of cold, and in less than their weight of boiling water. The reaction that takes place between the iron, the sulphuric acid, and the water, has been explained in page 18.

1028. Pour some strong sulphuric acid on iron-filings in a glass flask. Instead of a turbulent action taking place, as in the preceding instance, scarcely any traces of decomposition are observed ; if, however, the flask be now exposed to heat, the iron takes oxygen from part of the acid as well as from the water, sulphurous acid and hydrogen gases are disengaged, and the oxide of iron combines with another portion of the sulphuric acid which is not decomposed, and forms sulphate of iron. This process is never adopted for preparing the sulphate, but merely for experimental illustration.

1029. Sulphate of iron is sometimes required free from its

water of crystallization. For this purpose, it may be exposed to heat in an earthen vessel, till it becomes quite dry and of a greenish-white colour ; almost all the water is expelled in this manner, and the salt becomes at the same time quite opaque ; the heat must be applied by placing it over a furnace or good chauffer, taking care, however, not to allow the temperature to be so high as to expel any of the sulphuric acid, otherwise the salt will acquire a red colour, from the formation of some peroxide of iron.

1030. Dissolve some of the green crystals of the sulphate in spring-water ; the solution appears quite turbid, from the free oxygen which the water contains converting part of the oxide of iron in the sulphate into peroxide of iron, a subsulphate being deposited ; the acid that is sufficient to retain a given quantity of iron in the state of oxide in solution is not able to dissolve it at all, when it acquires an additional portion of oxygen. Drop a little sulphuric acid into the solution, and it will become quite clear, the precipitate being dissolved.

1031. Boil a solution of 300 grains of the crystallized green sulphate of iron in two or three ounces of water, with 100 or 150 grains of nitric acid, and evaporate the solution carefully in an earthen vessel till a red-coloured compound is obtained. Whenever the nitric acid is added to the solution, it assumes a very dark colour, and the dry mass which is afterwards obtained contains peroxide of iron, the oxide having attracted an additional portion of oxygen from the nitric acid. On digesting it in water, persulphate of iron (sesqui-persulphate) is procured in solution, and a reddish-brown matter, containing a great excess of peroxide, is left.

1032. A similar solution may be obtained, by exposing a solution of the green sulphate to the air for a long time, part of the peroxide that is formed being deposited.

1033. The different methods of preparing SULPHURET OF IRON have been described in 142, 316, 317.

1034. CARBONATE OF IRON may be obtained, by dissolving 143.62 grains of the crystallized carbonate of soda in cold water, pouring the solution into an ounce of water, in which 139.1 grains of the crystallized green sulphate of iron have been dissolved, stirring sufficiently, and collecting the precipitate on a filter.

The reaction that takes place is represented in the diagram (the salts being mixed in equivalent proportions), deducting the amount of the water of crystallization from the above quantities.

Fig. 194.

| Before Decomposition. | | After Decomposition. |

53.62 Carb. of Soda   { Soda .... 31.5 ------------- ∴ 7.7.6 Sulphate of Soda.
                               { Carbonic Acid 22.12

76.1 Sulph. of Iron   { Sulphuric Acid 40.1
                               { Oxide of Iron   36 ——————— 58.12 Carb. of Iron.
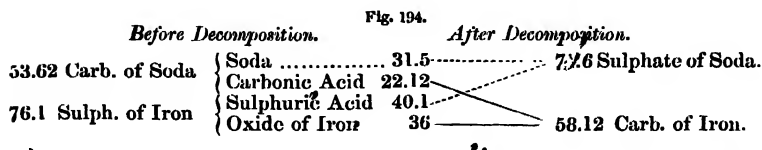
The sulphate of soda remains in solution, and the precipitated carbonate is to be washed on a filter with hot water, which has been boiled to expel the air it usually contains.

1035. This substance soon attracts oxygen from the air, and assumes the same appearance as the rust of iron, losing also the greater part of its carbonic acid. The compound, indeed, that is usually sold under the name of Carbonate of Iron, contains little or none, and is much less active and less soluble than the carbonate when newly precipitated. Mr Clarke has accordingly recommended it to be washed repeatedly in a deep jar, decanting the supernatant liquid when the precipitate subsides, and agitating it afterwards with more water, repeating this several times, so as to separate completely the sulphate of soda in solution. The precipitate must then be put on a cotton or linen cloth supported by a square frame, and, when water ceases to pass through, the edges must be gathered together so as to form a bag, from which the remaining water is to be squeezed by the hand. The carbonate procured in this manner gains little or no oxygen during the process, and, according to Mr Clarke, is little liable to change by keeping.

1036. Put some of the precipitated carbonate, after washing it with hot water, and while still moist, into a bottle half full of carbonic acid water, and shake them together. A solution of the bicarbonate of iron is obtained, which possesses the same properties as the carbonated chalybeate mineral waters, and in which the iron may be detected by the usual reagents. Expose part of it to heat in a Florence flask; the excess of carbonic acid is disengaged, and the carbonate is again precipitated.

1037. Put some iron-filings into a small flask or bottle, after exposing them to a red-heat in a crucible to decompose any oily matter, and pour in carbonic acid water till it is about two-

thirds full. On shaking it for a few minutes, part of the iron will be found to have been dissolved. In this case, the iron is oxidated at the expense of a portion of water which is decomposed, and is then dissolved by the carbonic acid. Dr Marshall Hall found that, when water is completely deprived of carbonic acid, iron does not decompose it at natural temperatures.

1038. Dr Ure recommends a similar solution to be prepared, by dissolving a little sulphate of iron and bicarbonate of potassa in cold water, agitating them together in a close vessel. The sulphuric acid of the sulphate may be supposed to combine with the potassa, forming sulphate of potassa, which does not particularly affect the rest of the liquid, the two equivalents of carbonic acid going to the oxide of iron, and retaining it in solution.

1039. The LIQUOR FERRI ALKALINI of the former London Pharmacopœia may be classed along with the carbonate of iron, as, from the mode of its preparation, its medicinal properties may be presumed to depend upon a bicarbonate of iron, though other opinions have been entertained with respect to the peculiar state of combination in which the iron exists; the following is the formula for preparing it:—Mix two drachms and a half of iron with two fluid ounces of nitric acid diluted previously with six fluid ounces of water, and, after all action has ceased, pour off the clear liquid, which is a solution of the nitrate of iron with excess of acid, and add it in small quantities at a time to six fluid ounces of a solution of the carbonate of potassa, made by dissolving four parts of the salt in three of water. The iron is thrown down at first of a reddish-brown colour, the nitric acid previously in combination with it uniting with part of the potassa, and disengaging carbonic acid, part of which escapes with effervescence, while the remainder combines with a portion of the carbonate of potassa that is not decomposed, and converts it into bicarbonate of potassa. On stirring the mixture with a glass-rod, the precipitated oxide or carbonate of iron is redissolved by the bicarbonate, and a solution is obtained of a very deep red colour ; it is then allowed to stand for six hours, when some crystals of nitrate of potassa are deposited, and the clear liquid is decanted. The solution is extremely apt to be decomposed, and the iron is thrown down even by diluting it with several times its bulk of water ; it must be kept in close vessels.

1040. ACETATE OF IRON may be prepared, by digesting iron in diluted acetic acid, or by adding a solution of the sulphate of iron to a solution of the acetate of lead, sulphate of lead being precipitated, while acetate of iron remains in solution. The tincture of the acetate of iron of the Dublin College is made, by mixing two parts of the acetate of potassa and one of sulphate of iron in an earthen mortar, till a soft mass is obtained, and digesting it afterwards in 26 parts of rectified spirit; sulphate of potassa remains. Acetate of iron is much employed in dyeing and calico-printing.

1041. The TARTRATE OF POTASSA AND IRON of the different Colleges, is prepared, by mixing two parts of the bitartrate of potassa, and one of iron-filings intimately together, and exposing the mixture for fifteen or twenty days to the air, moistening it frequently with water. The iron is oxidated, and combines with the excess of acid in the cream of tartar, remaining in combination with the neutral tartrate of potassa that is left: on boiling it for a short time in four times its weight of water it is dissolved. It may be obtained in the solid form, by filtering and evaporating the solution, but it does not crystallize.—See some observations on Tartrate of Iron by Dr Ure, *Quarterly Journal*, vol. vi. p. 388. According to the formula now adopted by the London College, three ounces of the peroxide of iron are digested for two hours in a sand-bath, with half a pint of the hydrochloric acid, and then mingled with two gallons of water. To the clear liquid, decanted after any sediment shall have subsided, potassa is added, by which the peroxide is thrown down in a minute state of division. After washing it frequently with water, it is boiled with eleven and a half ounces of cream of tartar in a gallon of water. The solution is neutralized, if acid, by a solution of the sesquicarbonate of ammonia, and then evaporated to dryness.

1042. GALLATE OF IRON may be formed by adding a solution of gallic acid to a solution of a salt of iron, being thrown down in the form of a dark coloured precipitate, which is the basis of writing-ink; gallic acid is never used, however, for this purpose in a pure state. The iron must be in the state of peroxide, as the protoxide is not precipitated by this acid.

1043. Many receipts have been given for the preparation of ink; the following is M. Ribaucourt's, *(Ure's Dictionary)*. Boil

two ounces of logwood in small chips with four ounces of galls reduced to a coarse powder, in six pounds of water, till half the liquid is evaporated. Strain the decoction through a linen cloth, and then add in fine powder two ounces of the sulphate of iron, half an ounce of the sulphate of copper, an ounce and a half of gum-arabic, and half an ounce of sugar. The mixture must be stirred till the liquid acquires a uniform appearance ; after allowing it to stand for twelve hours, the ink should be decanted and put into bottles.

1044. In this process, the gallic acid of the logwood and galls, along with the tannin, unites with the oxides of iron and copper of the salts, forming the dark coloured precipitate which is diffused through the liquid, and kept in suspension by the gum and the sugar, which are added to render it of a proper consistence. The sulphate of copper gives a deeper shade to the mixed precipitate, and retards moulding. When ink contains copper, it may be easily detected by metallic iron, a portion of which is taken up, on dropping a little ink upon it, and replaced by a coating of metallic copper.

1045. Pour a solution of chlorine in water into a little ink mixed with water ; the dark colour immediately disappears. The chlorine at once decomposes the vegetable matter, and if a solution of an alkaline hydrosulphate be then added to the liquid, sulphuret of iron will be precipitated.

1046. Write on some paper with common ink, and when it is dry, divide it into four pieces, and put them into a solution of chlorine in water till the writing disappears.

1047. The iron of the ink being still left where it was, the characters may be recalled ; put one of the pieces of paper into an infusion of galls, another into a solution of the hydrosulphate of ammonia, and a third into a dilute solution of the ferrocyanate of potassa. The oxide of iron will be rendered black by the infusion of galls and by the hydrosulphate, and blue by the ferrocyanate, and the characters, in general, can be distinguished as easily as before.

1048. Place the last piece of paper in hydrochloric acid diluted with 12 or 15 parts of water. All the iron will be dissolved in a short time, and then it will be impossible to recall the characters.

1049. Oxalic acid and some other acids can also dissolve the

iron, and hence they are employed for taking iron moulds from linen, being less corrosive than hydrochloric acid.

1050. If paper be written on with a weak infusion of galls, no characters will be visible when it is dry, but on dipping it into a solution of the sulphate of iron, they will immediately appear.

1051. Similar experiments may be made, by writing on paper with a solution of a persalt of iron, and dipping it into a solution of the ferrocyanate or sulphocyanate of potassa. The former renders the characters of a fine blue colour, and with the latter, they become of a deep red.

1052. Those varieties of ink which are not affected by chlorine, acids, or alkalis, usually contain carbon. Professor Traill has recommended the carbon to be suspended in a solution of gluten dissolved in acetic acid. Lamp-black is the carbon employed, being obtained in this condition in the minutest state of division. It should be carefully mixed in a mortar with the glutinous solution by long trituration.

1053. Some kinds of ink have lately come into use, which are of a blue colour at first, and others which remain blue. The sulphate of indigo is believed to be the ingredient which gives the blue colour. They have been described as indelible. Though not quite indelible, certainly they are not so easily destroyed by the usual agents as the common black ink. The only indelible ink is that containing free carbon.

1054. PERFERROCYANATE OF IRON (pure Prussian blue), commonly called Ferrocyanate of iron, is prepared by adding a solution of a persalt of iron to a solution of the ferrocyanate of potassa, as long as any precipitation takes place. If a solution of a protosalt of iron be taken, the precipitate that is thrown down is of a light colour at first, but absorbs oxygen when it is exposed to the air, and becomes blue. Many are of opinion, however, that the blue-coloured compound obtained in this manner, must differ in its composition from that which is precipitated blue at first, as we know that oxides in a high state of oxidation combine with a larger quantity of acids than when they contain less of this element; it is soluble to a certain extent in water, and cannot therefore be washed on a filter without considerable loss. It is destroyed by alkalis or alkaline car-

bonates, which unite with the acid and precipitate peroxide or carbonate of iron.

1055. .When very pure and dry Prussian blue is exposed to heat, it soon begins to undergo a kind of slow combustion, and is completely decomposed. Its use in the preparation of cyanogen and hydrocyanic acid will be considered afterwards.

1056. HYDROCHLORATE (OR MURIATE) OF IRON may be formed, by putting iron-filings or turnings into hydrochloric acid diluted with half its bulk of water. Part of the water is decomposed ; the oxygen goes to the iron, forming oxide of iron which is dissolved by the acid, and hydrogen gas is disengaged. The solution has a green colour, attracts oxygen when exposed to the air, and becomes perhydrochlorate of iron, some peroxide also being formed.

1057. Digest some of the peroxide or rust of iron in about four times its weight of hydrochloric acid ; a perhydrochlorate (with an excess of acid) is obtained in solution. It is this which is employed for the preparation of the tincture of iron, the hydrochlorate of the oxide of iron being insoluble in alcohol. If more peroxide be added, it is speedily dissolved, and Mr Phillips found that, in this manner, one equivalent of hydrochloric acid might be combined with ten of the peroxide of iron.

1058. When hydrochlorate of iron in solution is mixed with hydrochlorate of ammonia, and evaporated to dryness, a compound is obtained, which has been called the MURIATE OF AMMONIA AND IRON. It is recommended to be prepared by subliming mixtures of the two salts, or of hydrochlorate of ammonia and peroxide of iron, but it is seldom used.

1059. CHLORIDE OF IRON may be prepared, by evaporating a solution of the hydrochlorate to dryness, the oxygen of the oxide uniting with the hydrogen of the acid, and leaving the chlorine in combination with the iron.

IODIDE OF IRON may be procured by heating iron-filings with iodine and water, filtering the solution afterwards, and evaporating to dryness with a moderate heat.

CHAP. II.—LEAD

Symb. Pb. *Eq. by W.* 103.7. *Sp. gr.* 11.35. *It melts at about* 612°.

1060. Lead is generally obtained from galena, the native sulphuret of lead. To prepare a small quantity from this ore, reduce 240 grains to a fine powder, mix them with 112 grains of iron-filings, put the mixture into a common Hessian crucible, of which it should not fill more than a third, and expose it to a bright red heat for five or ten minutes in a chauffer with a chimney (page 10), or in a furnace. Part of the iron unites with the sulphur of the sulphuret of lead, forming sulphuret of iron, and the metallic lead is melted, and may be poured out when the crucible is removed from the furnace. If 20 or 30 grains of nitre be thrown into the crucible before it is withdrawn from the fire, and the whole be well stirred with an iron rod, little lead is lost, and it is more completely separated from the sulphur.

1061. In the diagram giving a view of the theory of the decomposition, only half the quantity of iron is represented, as 28 parts of iron are sufficient to combine with all the sulphur in 119.8 of the sulphuret, and an excess is employed, solely for the purpose of bringing the sulphur of the sulphuret into more intimate contact with the iron, which is not easily reduced to a minute state of division.

Fig. 195.

Before Decomposition.   *After Decomposition.*

119.8 Sulphuret of Lead { Lead 103.7——————103.7 Lead.
{ Sulphur 16.1

28   Iron......................................28————44.1 Sulphuret of Iron.

1062. On the large scale, lead is procured from the sulphuret, by reducing it to a rough powder, and exposing it to heat in a reverberatory furnace, adding portions of coal and limestone from time to time. The lime withdraws the sulphur (or sulphuric acid into which it is converted by the heated air). The

carbon of the coal takes oxygen from the oxide that is also formed, disengaging metallic lead ; or, oxide of lead and the sulphuret react on each other, giving metallic lead and sulphurous acid.   A quantity of slag collects, which consists chiefly of sulphate of lead, and is smelted in like manner to extract the lead it contains.   See par. 303, page 98.

1063. Lead may be obtained in a state of minute division mixed with carbon, by heating tartrate of lead or acetate of lead to redness in a covered vessel.   In this condition it takes fire spontaneously when brought in contact with the air.

1064. Lead usually contains a little iron, silver, and copper. When lead is required particularly pure for delicate experiments, it may be obtained by precipitation from a solution of any of its soluble salts.   Dissolve an ounce of the crystallized acetate of lead in 34 ounces by measure of water, and put a piece of zinc into the solution, suspending it at the top by a string fixed to a wire laid across the mouth of the jar or glass containing the solution ; part of the zinc is immediately dissolved, and the remainder is coated with metallic lead, which continues to be precipitated till the acetate has been completely decomposed, 32.3 parts of zinc (one equivalent) being taken up for every 103.7 of metallic lead (one equivalent) thrown down, so that a solution of the acetate of zinc remains.   If the solution be put into a long glass or jar, and not agitated, the lead is deposited in an arborescent form, presenting a very beautiful appearance ; it is in this manner that the *Lead Tree*, as it is termed, is commonly prepared.   The following diagram shows more precisely the nature of the reaction :—

Fig. 196.

Before Decomposition.   *After Decomposition.*

32.3 Zinc .... 32.3 ············· 91.78 Acetate of Zinc.

163.18 Acetate { Acetic Acid......... 51.48 ···
of Lead,   { Oxide of { Oxygen   8 ···
                {   Lead   { Lead 103.7 _____ 103.7 Lead.

Symb. Z & *A* ·Pb = *A* ·Z & Pb.
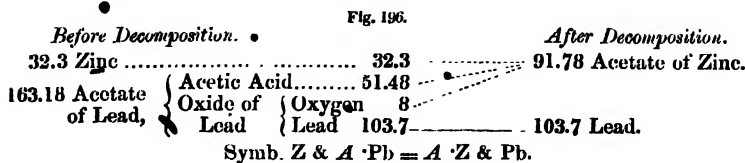
1065. Lead is speedily oxidated by the action of air and moisture, a carbonate of the oxide being formed.   It is corroded more speedily by distilled water freely exposed, than by water containing a portion of some saline compounds, as the phosphate

of soda, the sulphate of potassa, the hydriodate of potassa, common salt, &c.   When it is put in distilled water, and the air is carefully excluded, little or no action takes place ; but if the air be admitted, oxygen and carbonic acid are absorbed, and it becomes corroded.   A 27000dth part of phosphate of soda, a 12000dth part of arseniate of soda, or a 4000dth part of sulphate of soda in water, afford a complete protection when it is kept in leaden vessels, the carbonate that is formed at first being decomposed, and replaced by a thin film of an extremely insoluble salt formed by the union of the acid of the saline matter with the oxide of lead, which protects completely the rest of the lead from any farther corrosion. · Dr Christison's valuable work on Poisons contains many interesting observations on this important subject.

1066. Melt some metallic lead, and expose it to a red heat in an iron ladle or flat earthen crucible.   A film collects speedily on its surface, which consists of metallic lead mixed with the oxide.   Withdraw it from the fire, and remove from time to time the iridescent pellicle which gathers on its surface as it cools ; the tint depends upon the degree of oxidation.   If heated intensely in a current of air, the oxide formed is dissipated in vapour.

1067. Moisten some bone-ashes (which consist principally of phosphate of lime) after reducing them to a fine powder, make them into a shallow cup (called a *cupel*), of the form and size

Fig. 197.

represented in the figure, by kneading them in the hand ; place ten or twenty grains of lead above it, and expose it to a strong heat in a *muffle*, so that the air may have free access to it, while it is at the same time excluded from the action of the fuel.   The lead soon melts, acquires oxygen from the air, and is converted into oxide of lead, which is also melted, and absorbed by the bone-ashes.   As long as any metallic lead remains, it still rests on the top, the bone-ashes not absorbing any metallic particles, but only the melted oxide ; and if the lead contain any silver, it is left bright and brilliant on the cupel, after the oxidated lead is removed.   This is the manner in which silver is separated from lead.

1068. The experiment may be conducted in an open fire or furnace, taking care to support the cupel on a piece of brick,

and allowing fresh air to play upon it, while it is at the same time subjected to an elevated temperature. The cupel should also be loosely covered with a fragment of a crucible that no dust or ashes may fall upon it. The proper method of conducting this operation consists in placing the cupel in a muffle, described in the following paragraph.

1069. A *muffle* is an earthen vessel arched above and closed in at every side except in front, so that it may be exposed to a

Fig. 198.

very high temperature, by building it in a furnace in the manner represented in the adjoining figure, while any substance to be exposed to a high temperature, and to the action of the air at the same time, may be introduced at the open end. This furnace with the muffle is used in the process of *cupellation ;* a small portable furnace, with an opening at the side for putting in a small muffle, is often substituted for it.
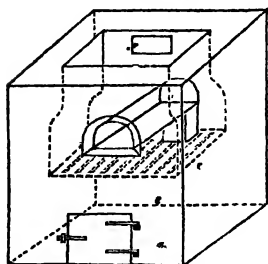
Muffles are used of all sizes, from two or three inches long and an inch and a half broad (to be used with a chauffer furnace) to fifteen or eighteen inches long and seven or nine broad. The one I generally use is ten inches long, five broad, and about four and a half high. •

1070. A muffle should never be exposed suddenly to a strong heat, as it is then very apt to crack. The fire must be raised very gradually, beginning at first with little more than may be necessary to prevent it from going out. The fuel is introduced from an opening above, and great care must be taken not to allow any of it to fall directly upon the muffle. The bottom should rest on a brick about four or five inches above the branders, and its sides should be at least two inches from the side walls of the furnace, that the fuel may fall readily below.

1071. The little cup made of bone-ashes (1067) is usually termed a cupel, and is prepared most easily by driving pounded bone-ashes (a little wood-ashes being sometimes added) into a small brass mould, by means of a pestle struck forcibly by a wooden mallet. It must then be removed cautiously, placed on a piece of paper, and dried before using it. The mould is

open above and below, and may be compared to the section of a tube with thick sides. The pestle is made so as to give the necessary depression. See Fig. 199.

Fig. 199.

1072. In conducting the experiment above described, for the sake of illustration, the cupellation furnace should be preferred; but where the student has not the advantage of a furnace of this description, the cupel may be placed on a piece of brick, or other support, in an open fire, maintaining a high temperature, and allowing the air to have free acess through the branders.

1073. Lead is readily dissolved by diluted nitric acid, with which it forms a very soluble salt. It is not acted upon by hydrochloric acid or cold sulphuric acid, and is slowly oxidated and a sulphate formed by the latter acid while hot. Almost all its salts are insoluble or very sparingly soluble, except the nitrate and the acetate. It is separated from its soluble salts by iron or zinc, if there be no excess of acid present.

1074. To prepare OXIDE (PROTOXIDE) OF LEAD (*Symb.* OPb, *or* ·Pb. *Eq. by W.* $111.7 = O.8 + 103.7$ Pb), add a solution of potassa or ammonia to a solution of the nitrate of lead, as long as any precipitation takes place; wash the precipitated hydrate or subnitrate, which is of a white colour, and, to expel the water and remaining nitric acid, expose it to heat in a crucible placed in the fire, taking care not to urge the heat, otherwise the oxide will melt, and soon destroy the crucible, the siliceous matter which it contains forming a very fusible glass with the oxide of lead. A platinum crucible is best for this operation. The oxide may also be procured by exposing the nitrate or carbonate to a dull red heat. The oxide of lead thus procured is of a yellow colour.

1075. The *Massicot* of commerce, which is of a fine yellow colour, is also oxide of lead, and is prepared by exposing the crust that forms on the surface of melted lead to heat and air. By heating it till it has been partially fused, it is obtained in the form of scales, which have usually a reddish-colour, arising from the formation of a small portion of the red oxide of lead, and in this state it is termed *Litharge*. From its forming a fusible compound with earthy substances, it is used in the manufacture
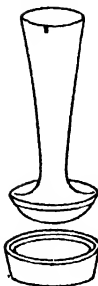
of flint glass.   It was formerly much employed to give a glazing for earthenware and porcelain.

1076. Add a solution of potassa, soda, or ammonia, to a solution of the acetate of lead.   The alkali combines with the acid, and oxide of lead is immediately precipitated in combination with a portion of water, and of a white colour.   It is redissolved by an excess of potassa or of soda.   It is the only oxide of lead that forms salts with the acids.

1077. DINOXIDE of Lead ($Symb.$ OPb^2, or $\cdot Pb^2$; $Eq.$ by $W.$ $215.4 = O.8 + 207.4$ Pb).   This compound is prepared by exposing dry oxalate of lead to a dull red heat in a covered vessel so as to prevent access of air.   Carbonic acid and carbonic oxide gases are expelled, and a dark grey powder, dinoxide of lead remains.   Sulphuric, hydrochloric, and acetic acids resolve it into metallic lead, and oxide of lead with which the acid combines.

1078. QUADROTRISOXIDE OF LEAD (called also, $Deutoxide$, Red $Oxide$ of Lead, Red $Lead$, $Minium$). $Symb.$ O^4Pb^3, or $\cdot\colon Pb^3$, or $2\cdot Pb + \colon Pb.$ $Eq.$ by $W.$ $343.4 = O.32 + 311.1$ Pb.   This compound of oxygen and lead cannot be prepared easily on the small scale ; it is formed by directing a stream of air upon the heated oxide and stirring it till it acquires a red colour, taking care not to melt it.   By exposure to a stronger heat, it parts with a portion of its oxygen, and oxide of lead remains.   It may be regarded as a compound of two equivalents of the oxide, and one of the binoxide.   Dr Thomson considers that the proportion of oxide in this compound varies, perhaps from its not being well prepared in some instances.   Red lead is much employed as a pigment.

1079. BINOXIDE (or PEROXIDE) of Lead. $Symb.$ O^2Pb, or $\colon Pb$; $Eq.$ by $W.$ $119.7 = O.16 + 103.7$ Pb.   To prepare BINOXIDE OF LEAD, 232 grains of the red oxide may be digested in a Florence flask for a short time, with 2 drachms of nitric acid, and 3 ounces of water.   The $oxide$ combines with the acid, and forms nitrate of lead, which remains in solution, leaving the brown binoxide, which may be separated by filtration.   It is not applied to any use.   I have met with several accounts of the action of nitric acid on the red oxide of lead, in which it is affirmed that it becomes white, and that much more than half of this oxide, instead of less, is removed by the nitric acid.

I have never seen it rendered white by the action of nitric acid. It is decomposed by a red-heat, oxygen being given off, and oxide of lead left. It may also be formed by passing a stream of chlorine gas through a solution of the acetate of lead.

1080. Salts of lead in solution are easily detected by a stream of hydrosulphuric acid gas applied in the usual way, the sulphur of the gas combining with the metallic lead, and forming a brownish-black sulphuret; which is precipitated, while the hy-, drogen unites with the oxygen of the oxide and forms water. A solution of the hydrosulphate of ammonia may be used instead of hydrosulphuric acid gas.

1081. When silver, bismuth, or mercury, and some other metals may be present in' the solutions examined, the black precipitate thrown down by hydrosulphuric acid cannot be relied on as an indication of the presence of lead, as these metals also give a dark precipitate with this gas. Should it be necessary, therefore, to distinguish the precipitated sulphuret from other sulphurets presenting a somewhat similar colour, collect the precipitate, wash it on a filter, and digest it in diluted nitric acid. Evaporate the solution to dryness to dissipate any excess of the acid, make a solution in water of the residue, and test it with a solution of the hydriodate of potassa. If lead be present, a yellow precipitate of iodide of lead will immediately be formed. Or the nitrate thus procured may be tested with the bichromate of potassa, which occasions a fine yellow-coloured precipitate of chromate of lead (chrome-yellow).

1082. Exposed to heat before the blowpipe and on charcoal, most of its salts readily give a globule of metallic lead.

1083. Solutions of the soluble salts of lead are transparent and colourless, and give copious precipitates of a white colour with alkalis and alkaline carbonates, consisting of oxide and carbonate of lead. Sulphuric acid and solutions of sulphates throw down a white precipitate of the sulphate of lead ; hydrochloric acid and solutions of hydrochlorates give a white precipitate of chloride of lead, the chlorine of the acid uniting with the metallic base of the oxide, while its hydrogen combines with the oxygen. Hydriodate of potassa gives a rich yellow-coloured precipitate, which is composed of iodine and metallic lead, a reaction taking place similar to what has been explained with

respect to hydrochloric acid and oxide of lead.   Ferrocyanate of potassa and infusion of galls give each a white precipitate.

1084. Mr E. Davy has pointed out another method of detecting lead and some other metals, which consists in placing the liquid suspected to contain lead on a slip of platinum, and touching it with a piece of zinc at that point; a little acid being put along with the liquid under examination upon the platinum.   A .galvanic action is immediately established, and, should any lead be present, it is immediately precipitated in the metallic form upon the platinum.

1085. NITRATE OF LEAD may be obtained by digesting oxide of lead or metallic lead in nitric acid diluted with seven parts of water, continuing the heat as long as any effervescence takes place, and evaporating the solution after filtration, till a pellicle appears on its surface, when it may be set aside to crystallize. The crystals are octohedral, contain no water, and deflagrate when heated with inflammable matter.   They are soluble in about seven parts of boiling water.   Nitrate of lead is used in practical chemistry to furnish nitrous acid, which it gives out when heated, and (it or the acetate) to indicate the presence of sulphuric acid, with which or salts of which, it gives a white precipitate, insoluble in nitric acid, whereas other white precipitates of lead as the oxalate or carbonate of lead, &c. are redissolved by nitric acid.   It is used occasionally in the art of calico printing, to furnish oxide of lead for the formation of the chrome yellow. Several other nitrates have been described, in which more of the oxide is combined with the nitric acid.

1086. SULPHATE OF LEAD is formed whenever sulphuric acid, or a solution of a sulphate, is added to a solution of a salt of lead; it is very insoluble, and every 151.8 parts (one equivalent) contain exactly 103.7 of metallic lead.   The quantity of lead in a solution of a salt of lead may be easily ascertained, by precipitating it in the form of sulphate of lead, and carefully drying and weighing the precipitate.   Cold sulphuric acid does not act upon lead, but when this metal is boiled in the strong acid, it is oxidated, unites with a portion of the acid, and forms sulphate of lead, while sulphurous acid is given off.   Strong sulphuric acid dissolves a small quantity of this salt (306).   It is also slightly soluble in solutions of alkalis and their carbonates.

Metallic lead appears when the sulphate is heated on charcoal before the blowpipe.

1087. PHOSPHATE OF LEAD is very insoluble. A compound of phosphoric acid and oxide of lead may be obtained by adding a solution of the phosphate of soda to a solution of the acetate of lead, or to a hot solution of the chloride of lead.

1088. CARBONATE OF LEAD may be prepared by adding a solution of an alkaline carbonate to a solution of the nitrate or acetate of lead. On the large scale, it is prepared by exposing thin sheets of metallic lead to the vapour of vinegar. It is usually called *Cerusse* or *White Lead*. On the continent it is prepared by transmitting carbonic acid gas from the combustion of charcoal through a solution of the subacetate of lead. Carbonate of lead is precipitated, and a solution of the acetate remains, which is restored to the state of subacetate by digesting it with litharge. It is found native. The carbonate, according to Dr A. T. Thomson, is the most poisonous of the salts of lead. And those its salts which most easily pass into the state of carbonate, as the subacetate, are also of a poisonous nature. By mixing the latter with vinegar, it is prevented passing into carbonate, and may then be taken with safety into the stomach.

1089. ACETATE OF LEAD, or *Sugar of Lead*, may be obtained by boiling Carbonate of Lead in diluted-acetic acid. The carbonate should be boiled with the acid, till it ceases to take up any more ; the solution is then filtered through paper, and evaporated till a pellicle appears on its surface, the acetate being deposited as it cools, in needle-shaped crystals, which are six-sided prisms and contain 3 eqs. of water. They are soluble in a little less than four parts of water, and the solution has a sweet but styptic taste. Acetate of lead is much used in dyeing and calico printing, to give acetate of alumina or of iron from their sulphates, and to furnish lead for chrome colours. It is seldom made on the small scale, being manufactured abundantly. On the large scale it is prepared by digesting oxide of lead in strong acetic (pyroligneous) acid.

1090. Dissolve some acetate of lead in spring water ; the solution is often quite turbid, the sulphuric and hydrochloric salts, which it generally contains, precipitating part of the lead, as sulphate and chloride of lead ; the latter, however, may be retained in solution when the quantity of water is considerable.

1091. Carbonic acid also produces a precipitate ; filter a solution of the acetate, and add some carbonic acid water to the clear liqtor ; a copious precipitate is thrown down, consisting of carbonate of lead, and if a stream of carbonic acid be passed through the solution for some time, half of the oxide is separated, the acetic acid previously in combination with it combining with the acetate which is not decomposed, and converting it into binacetate of lead, which remains in solution, and is not decomposed by carbonic acid.

1092. The DITACETATE OF LEAD, commonly called the SUBACETATE OF LEAD, is prepared by boiling an excess of the yellow oxide of lead, or litharge, reduced to a fine powder, in diluted acetic acid ; or a solution of the acetate may be used, which will afford a similar solution with the oxide of lead more speedily. 190.18 grains of the crystallized acetate may be taken, with 111.7 of the oxide of lead, and about nine ounces of water, previously boiled for some time to expel all the carbonic acid which it may contain. It bears a considerable resemblance to the acetate in all its leading chemical relations, but is more easily decomposed, and is also more readily affected by carbonic acid. It precipitates many organic compounds, and is hence sometimes employed in analysis. When its solution has been sufficiently evaporated, it is deposited, on cooling, in the form of a shining crystalline powder, having a pearly aspect. It is known by the name of *Goulard's Extract*, and consists of two equivalents of oxide of lead and one of acetic acid. Many, however, consider that Goulard's extract, when properly prepared, consists of three equivalents of oxide of lead and one of acetic acid. Some new compounds of acetic acid and oxide of lead have been lately described.

1093. CHLORIDE OF LEAD may be procured by adding hydrochloric acid, or a solution of a hydrochlorate, to a salt of lead dissolved in water. It is precipitated in small white crystals, unless the solutions be very dilute. It may also be formed by heating thin sheet lead in chlorine. It fuses readily, and on cooling forms a semitransparent horn-like mass, *horn lead*. It is soluble in 30 parts of water at 60° and a little more than 20 at 212°. *Patent yellow* is a mixture of chloride and oxide of lead made from moistened common salt and litharge. The mass is washed, to remove any soda formed, and then fused.

1094. IODIDE OF LEAD is prepared by adding a solution of 165.7 parts of iodide of potassium to a solution of 190.18 parts of the crystallized acetate of lead. Iodide of lead is immediately precipitated of a yellow colour, acetate of potassa remaining in solution. The diagram explains the action more particularly.

Fig. 200.

Before Decomposition.			After Decomposition.
165.7 Iodide of Potassium	{ Potassium	39.2	96.68 Acetate of Potassa.
	Iodide...	126.5	
163.18 Acetate of Lead	{ Acetic Acid	51.48	
	Oxygen......	8	
	Lead	103.7	230.2 Iodide of Lead.

Symb. IK & A ·Pb $= A$ ·K & IPb.
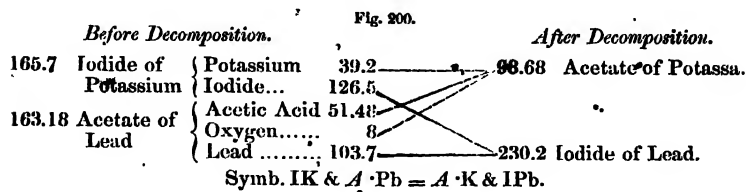
190.18 parts of the crystallized acetate of lead contain 163.18 of the dry acetate.

CHAP. III.—COPPER.

Symb. Cu.   *Eq. by W.* 31.7.   *Sp. gr.* 8.8.   *Melts at* 1996°
(Daniell.)

1095. Native copper is not abundant. The copper of which such large quantities are employed in the various arts, is extracted from ores of this metal, of which there are some rich mines in Cornwall. There are chiefly two ores from which copper is extracted; *copper pyrites,* consisting of sulphuret of copper and sulphuret of iron; and *grey copper-ore,* which, besides sulphuret of copper, contains sulphuret of antimony, arsenic, or silver. These ores are mixed with a quantity of siliceous matter, which is of some service in aiding the reduction of the ore.

1096. The ore is first roasted in a reverberatory furnace without fusing it, by which the arsenic and a great portion of the sulphur are driven off, and part of the iron is oxidated. It is then placed in a melting furnace and fused, being frequently stirred at the same time. A slag, consisting of siliceous matter and the oxide of iron, is separated, rises to the surface, and is removed. An additional quantity of roasted ore is added, the slag again

skimmed off, and this repeated until the furnace is full. The fused mass is then run into water. It is again roasted, for a longer period, in a reverberatory furnace, to oxidate the iron and dissipate the sulphur more completely, melted, and slag separated as before. This is again repeated. It is then melted and exposed to a current of air at a high temperature. Lastly, it is *refined* or *toughened* by again heating it, melting it, covering it with charcoal, and stirring it with a pole (of birch) put into the fluid mass. This completes the deoxidation of the copper, and it is now possessed of that tenacity, malleability, and ductility for which it is so much prized. Frequently iron, or silica, or some of the slag, or unreduced ore, requires to be added in the first and second operations, according to the composition of the ore.

1097. A finer kind of copper, supposed to be more free from oxide, was prepared by Mr Mushet, by fusing it again and adding about $\frac{1}{500}$ of its weight of zinc. It is probable that the zinc carried off the remaining oxygen in the form of oxide.

1098. Copper is procured in small fragments by melting it and pouring it through a perforated ladle into water. If the water be warm, the copper forms *bean-shot*, of a smooth rounded form; if kept cold, the copper then forms *feathered-shot*, which has ragged edges.

1099. When copper is required extremely pure, or in a very minute state of division, it may be obtained by putting a piece of zinc into a solution of the sulphate of copper, the zinc taking the oxygen of the oxide of copper and the sulphuric acid, and sulphate of zinc remaining in solution, while the copper is precipitated in the metallic form. Iron may be used instead of zinc ; in either case, the metal employed to precipitate the copper from the solution may be left in the liquid, till its blue colour almost entirely disappears.

1100. If a piece of copper be required with a bright metallic surface, it may easily be obtained by rubbing it with a piece of cloth dipped in dilute hydrochloric acid. If a piece of copper be exposed to a red heat for ten minutes, a film of oxide is formed on its surface, and on plunging it into cold water, the metal that still remains immediately contracts, and the oxide is thrown off in scales, leaving the copper of its characteristic tint.

1101. Copper has a peculiar red or reddish-brown colour. It is rather a hard metal, but at the same time possesses malleability and ductility in a high degree. In tenacity it is inferior only to malleable iron. It is said to vaporize when heated intensely ; and is oxidated and burns with a greenish light under the oxy-hydrogen blowpipe.

1102. Copper is slowly oxidated at ordinary temperatures in an atmosphere not free from watery vapour and carbonic acid, becoming covered with a greenish crust of carbonate of the oxide of copper. It is not oxidated by water even at a red heat, unless air or free oxygen be present. At a red heat it is quickly oxidated in air, scales of the *black oxide* being formed. At lower temperatures than a red heat, it absorbs less oxygen, and becomes coated with a very thin film of *red oxide*, which give it a yellow, orange, or brown colour, according to the degree of oxidation. In this manner, vessels, &c. made of copper are frequently bronzed. Copper is acted on slowly by the sulphuric and hydrochloric acids, unless the acids are strong and at a high temperature. Chlorine quickly acts on copper when the metal is in fine leaf (548). Nitric acid is its proper solvent, acting on it as has been described in par. 164–5.

1103. DINOXIDE OF COPPER (Suboxide or Red Oxide of Copper). *Symb.* OCu^2, or $\cdot Cu^2$; *Eq. by W.* 71.4 $=0.8 + 63.4$ Cu). This is a native production, found in copper-mines, in octohedral crystals of a dark red colour. It may be procured by adding potassa to a solution of hydrochlorate of the dinoxide of copper, being then precipitated of an orange colour in union with some water. It may be also prepared by mixing intimately, and heating in a crucible, equivalent weights of copper in filings, and the oxide of copper ; or, thin sheets of copper heated with alternate layers of the oxide, out of access of air, may be employed. It may also be formed by fusing the hydrochlorate of the dinoxide of copper with an equal weight of carbonate of soda. Chloride of sodium and red oxide of copper are procured, and the chloride is removed by solution in water.

1104. The dinoxide has a great tendency to pass into oxide. At a red heat it absorbs oxygen and becomes black oxide. By strong hydrochloric acid it is dissolved, and also by ammonia, colourless solutions being formed in both cases. The solution in ammonia speedily becomes blue when exposed to the air, oxy-

gen being absorbed. Dilute acids resolve it into oxide of copper, with which the acid unites, and metallic copper.

1105. Oxide of Copper (called also Peroxide of Copper, Black Oxide of Copper). *Symb.* OCu or ·Cu ; *Eq. by W.* 39.7 = O.8 + 31.7 Cu. The black oxide occurs native, forming what is called *Copper Black.* It may be prepared by adding potassa in excess to the sulphate or nitrate of copper, and heating the precipitated oxide to expel any water ; a disulphate is first formed. When the nitrate of copper is exposed to a red heat in a crucible, the acid is expelled and oxide of copper is left. When metallic copper is highly heated, a coating of this oxide is formed on its surface, which separates in scales as the metal cools and contracts, or may be more quickly removed by plunging it while hot into cold water. There is a very thin film of metallic copper on its inner surface, which may be oxidated by keeping the scales at a red heat for some time in contact with air.

1106. Expose some of the oxide of copper to a bright red heat in a crucible, with a seventh part of its weight of charcoal. Carbonic oxide is disengaged, and the copper is procured in the metallic form.

1107. This is the basis of the salts of copper, uniting with the acids, and forming with them compounds of a blue or green colour, chiefly very soluble. It is not soluble in solutions of the fixed alkalis, but when fused along with their carbonates, the carbonic acid is expelled, and a compound of the alkali and the oxide of copper is left. It is particularly distinguished by its solubility in ammonia.

1108. Put some of the oxide of copper into a small bottle nearly full of the water of ammonia, and shake it frequently. Part of the oxide is dissolved, and the solution has a very rich blue colour. If a quantity of copper-filings be added to the solution, and the bottle well closed, so as completely to exclude the access of air, one portion of the metallic copper combines with part of the oxygen in the oxide, reducing it to the state of dinoxide, while the metallic copper is also converted into dinoxide, and a clear and colourless solution is obtained in a few days, consisting of water of ammonia and dinoxide of copper. If the cork be then opened, and air be allowed to enter freely, the

blue colour again returns, the dinoxide attracting oxygen, and being converted into oxide.

1109. Put some metallic copper into water of ammonia, and allow them to remain mixed together for some hours; the copper acquires oxygen from the water, and a small portion of oxide is formed; this is speedily dissolved by the ammonia, and the usual blue colour appears. In this experiment the air communicates oxygen to the water, and this element is then handed over to the copper. The preceding experiment (1108) proves that copper is not oxidated by water when the air is excluded.

1110. Hence copper vessels may be safely used for preparing various liquids, without any risk of copper being dissolved, if care be taken that the liquid contain no free oxygen. Even many acid liquids do not corrode copper vessels in which they are merely boiled, though they corrode it rapidly when they are left in it at natural temperatures, and freely exposed to the air, oxygen being then absorbed. During ebullition, this is not only prevented, but any which the liquid may have previously attracted is expelled.

1111. BINOXIDE OF COPPER. Symb. O^2 Cu or :Cu. Eq. by W. $47.7 = 0.16 + 31.7$ Cu. It was prepared by Thenard by the action of hydrate of the oxide of copper with diluted binoxide of hydrogen. It must be quickly dried in vacuo over sulphuric acid. It contains two equivalents of oxygen and one of copper.

1112. Copper is in general easily recognised, when in solution, by the deep blue or green colour which it communicates to the liquid in which it is dissolved, and by the precipitation of metallic copper that takes place, on introducing a piece of zinc or iron after neutralizing any excess of acid that may be present. Ammonia, added to a solution of any of the salts of copper, unites with the acid, and precipitates oxide of copper, which may be redissolved by an additional quantity of ammonia, the solution then acquiring the deep blue colour that indicates the presence of this metal. In solutions of salts of nickel, a similar effect is produced. Copper and nickel may be distinguished by ferrocyanate of potassa (1114).

1113. When copper is present in a very small quantity, more especially when it is mixed with organic matters, the materials under examination ought first to be boiled with water; the copper is then to be precipitated by hydrosulphuric acid, boiling

the liquid afterwards to expel any excess of gas, and digesting the precipitate in nitric acid diluted with an equal weight of water ; after which, on adding an excess of ammonia, the characteristic blue colour appears. It is necessary to incinerate the precipitated sulphuret, before treating it with nitric acid, that any animal or vegetable matter mixed with it may be destroyed. Dr Christison has pointed out the important improvement of treating the substance under examination with diluted acetic acid, before passing the hydrosulphuric acid through the solution obtained by boiling with water, as this acid removes oxide of copper from many animal and vegetable matters, affording, therefore, in numerous instances, a larger quantity of material to operate upon.

1114. Ferrocyanate of potassa gives a very characteristic precipitate with solutions of salts of copper. It consists of ferrocyanate of copper, and has a dark mahogany colour. With salts of nickel, the ferrocyanate of potassa gives a greyish-white precipitate. Galls give a brown precipitate with salts of copper.

1115. With hydrosulphate of ammonia and salts of copper, a brownish-black precipitate is produced. Sulphuret of copper and water are formed, the ammonia remaining in combination with the acid formerly combined with the copper.

1116. All the salts of copper communicate a green or blue tint to inflammable matter in a state of combustion, when they are moistened. This is best shewn by mixing ten or twelve grains of the hydrochlorate of copper with half an ounce of alcohol, and exposing the mixture to a good heat over a chauffer, inflaming the alcohol whenever it begins to boil. The colour is usually green at first, but passes ultimately to a fine blue.

SALTS OF COPPER, &c.

1117. The salts of the dinoxide are generally free from colour, but those of the oxide have a deep blue or green colour.

1118. To prepare NITRATE OF COPPER, put two parts of copper-clippings into four of nitric acid, diluted with twice its bulk of water, and digest the mixture for a short time, till all effervescence ceases. Then pour off the clear solution, and evaporate it till a pellicle begins to appear on its surface, when it may be set aside to crystallize. During the solution of the

copper in the acid, a large quantity of irritating fumes are produced, which ought to be carefully avoided ; they are formed by the binoxide of nitrogen that is disengaged attracting oxygen from the air and being converted into nitrous acid (See 164-5). Nitrate of copper is a very deliquescent salt, and must accordingly be kept in close vessels ; the crystals are prismatic and of a fine blue colour. They have an acrid taste, and are rather caustic. Nitrate of copper is soluble both in water and in alcohol. Its crystals contain a considerable quantity of water of crystallization. They liquefy at about 100°, lose their water and part of their acid by a higher temperature, and at a red-heat nothing remains but oxide of copper. It has been used lately with great success as an escharotic.

1119. Spread a drachm or two of the nitrate in powder on a piece of tin-foil several inches square, moisten it with two or three drops of water, and fold it up quickly, taking care to throw it down whenever it begins to grow hot. The tin decomposes it, attracting oxygen ; great heat is produced at the same time, and a quantity of gas is evolved ; a number of sparks are also seen, small portions of the tin burning with a red light.

1120. Subject nitrate of copper to a temperature of about 400° : part of its acid is discharged, and a trinitrate or subnitrate is left, of a deep green colour. It is insoluble in water. It consists of 3 eqs of oxide of copper, 1 of acid, and some water. This salt is precipitated also when potassa is added to an excess of the nitrate.

1121. SULPHATE OF COPPER is seldom prepared in the laboratory, as it is manufactured in large quantities for use in the arts. It is procured by evaporation from mineral waters of copper mines ; formed by the oxygenation of the native sulphuret, by roasting it, and exposing it to air and moisture ; or by dissolving the oxide in diluted sulphuric acid. It may also be formed by boiling sheet-copper or copper-filings in strong sulphuric acid, sulphurous acid being given off. It is the residuum of some operations for refining gold and silver. It has been long known by the name of *blue vitriol*. Its solution in water crystallizes readily, when evaporated till a pellicle appears on its surface. The crystals are of a blue colour and soluble in four parts of cold and in two of boiling water. They contain about five equivalents of water of crystallization. All the water is

x

driven off by a heat a little above 430°, and by a higher tempe-
rature, the acid is expelled and oxide of copper remains.   It is
employed as an escharotic.

1122. The AMMONIATED COPPER of the different Colleges,
called also, SULPHATE OF AMMONIA AND COPPER, is prepared
by mixing two parts of crystallized sulphate of copper with
three of the sesquicarbonate (common carbonate) of ammonia,
rubbing them in a mortar till they become quite moist, and till
the mixture acquires a very rich blue colour ; it should then be
dried with a very gentle heat, or simply by bibulous paper,
and put immediately into bottles which must be well stopped.
In this process, the ammonia of part of the carbonate unites
with the sulphuric acid and oxide of copper in the sulphate, and
carbonic acid is disengaged with effervescence, the water of
crystallization in the sulphate being set at liberty, and rendering
it quite moist.   It contains sulphuric acid, oxide of copper,
ammonia, a considerable quantity of water, and perhaps some
carbonic acid. If it be exposed freely to the air for some time, part
of the ammonia is disengaged, and it loses its fine blue colour.

1123. SULPHURET OF COPPER (composed of one eq. of each
ingredient) is formed when a stream of hydrosulphuric acid gas
is transmitted through a solution of the sulphate of copper.   It
is precipitated of a dark brown colour, gradually deepening in
tint.   When exposed to a strong heat, half of its sulphur is ex-
pelled, and a disulphuret remains.   Common copper-pyrites
contains the sulphuret, associated with sulphuret of iron.

1124. DISULPHURET OF COPPER (consisting of one eq. of
sulphur and two of copper) may be formed by heating 8 parts
of copper-filings and 3 of flowers of sulphur, previously inti-
mately blended together.   During the combination, heat and
light are evolved.   The experiment may be made in a Florence
flask, heated over a chauffer or lamp in the manner described
in 317, page 104.   The native ore called *glance-copper* is a di-
sulphuret.

1125. DICARBONATE OF COPPER is easily obtained by adding
a solution of the carbonate of potassa to a hot solution of the
sulphate of copper, as long as any precipitation takes place.   It
contains two eqs. of the oxide of copper, one of carbonic acid,
and one of water.   It is of a greenish-blue colour, and dissolves
with effervescence in diluted sulphuric, nitric, hydrochloric, and

acetic acids. By heat, the carbonic acid and water are expelled, and oxide of copper remains. *Mineral green*, and the native green copper-ore, *malachite*, are similar in composition.

1126. By boiling the precipitated dicarbonate in fine powder in water, it becomes brown, having lost its water according to some, and its carbonic acid also, according to others. The dry dicarbonate occurs native in India.

1127. The greenish rust formed on metallic copper when exposed to air and moisture, is a dicarbonate, in union with water.

1128. BLUE VERDITER is a compound of carbonic acid and oxide of copper with a little water. It is formed by the action of chalk with nitrate of copper, or by precipitation from a diluted cold solution of sulphate of copper by carbonate of potassa. It contains two eqs. of carbonic acid, three of oxide of copper, and one of water. The native mineral, called *blue copper-ore*, is of the same chemical constitution.

1129. ACETATE OF COPPER (or crystallized verdigris). This salt is prepared by dissolving common *verdigris* in distilled vinegar (acetic acid), evaporating the solution till a pellicle appears upon its surface, and crystallizing, when oblique rhombic prisms of a bluish-green colour appear. The crystals are sparingly soluble in alcohol. They are dissolved by twenty parts of cold, and five of boiling water. They contain one eq. of acetic acid, one of oxide of copper, and one of water. It is slightly efflorescent. When distilled, it yields strong acetic acid ; and in the retort a mixture of carbon and oxide of copper (or metallic copper in a minute state of division) remains, which is sometimes spontaneously inflammable.

1130. DIACETATE OF COPPER (subacetate of copper, or VER-DIGRIS). This salt is extensively used as a pigment. It is prepared by exposing thin sheet copper to the action of acetic acid (vinegar is used) or its vapour. Sheets of copper, in contact with alternate layers of cloth steeped in vinegar, become soon covered with verdigris, which is then removed, and the remaining copper exposed in the same way. The refuse of the wine manufacture, in a state of acetous fermentation, is employed on the Continent to yield the acetic acid. It forms in needle-shaped crystals, of a silky lustre, and a blue colour. It consists of one eq. of acetic acid, two of oxide of copper, and about six of water.

The peculiar action of water upon it will be mentioned immediately, see 1132.

1131. Verdigris is frequently adulterated with chalk or plaster of Paris. To detect either of these substances, all that is necessary is, to mix some with water in a glass, adding a little sulphuric acid, and stirring the mixture with a glass-rod. All the verdigris will be dissolved, and a blue-coloured solution of the sulphate of copper will be formed, the acetic acid of the verdigris remaining in the liquid ; if any sulphate of lime or chalk should have been mixed with it, a white powder will remain at the bottom of the liquid.

1132. Digest verdigris for half an hour in five or six times its weight of water in a Florence flask. It is resolved into two salts, one which is insoluble, and another which remains in solution in the liquid. Three eqs. of verdigris give one eq. of each of these salts, as is represented in the following diagram. The water of the verdigris and of the salts formed is omitted.

Fig. 201.

```
           ( 2 Acet. Acid  102.96----------222.06 Sesquiacetate of Copper
2 eqs.     ) 2 Oxide Copp.  79.4----
Verdigris, ) 1 Oxide Copp.  39.7--
           ( 1 Oxide Copp.  39.7
           ( 2 Oxide Copp.  79.4
1 eq.      ) 1 Acet. A.     51.48---------170.58 Tritacetate of Copper.
Verdigris, (
           Symb. 3(A + 2·Cu) = 2 A + 3·Cu & A + 3·Cu.
```
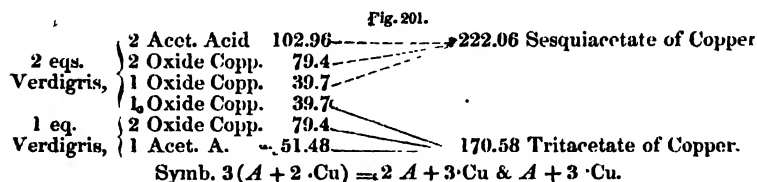
1133. The Sesquiacetate is the soluble salt. The Tritacetate is insoluble. They may be separated by filtration. The sesquiacetate contains about six equivalents of water, the tritacetate only two.

1134. Chlorine readily combines with copper if introduced into the gas in the state of filings or fine leaf. It takes fire, and both chloride and dichloride of copper are formed. See par. 548. The former compound is volatile, the latter is fusible, but not so readily vaporized.

1135. Chloride of Copper (*Symb.* ClCu ; *Eq. by W.* 67.2 = Cl 35.5 + 31.7 Cu). This is best procured by evaporating a solution of hydrochlorate of copper to dryness, by a heat not above 4t°. If the heat be too great, half of the chlorine is expelled, and the dichloride remains. It is of a yellow colour, but in contact with air, absorbs moisture, and becomes white and then green.

1136. The HYDROCHLORĀTE OF COPPER, or hydrate of chloride of copper, may be procured by digesting the oxide of copper in hydrochloric acid diluted with an equal bulk of water. The precipitated dicarbonate may be used instead of the oxide. On concentrating the liquid, green acicular crystals are procured. These are very soluble both in water and alcohol, and are also deliquescent. Its solution is of a dark green colour.

1137. DICHLORIDE OF COPPER (*Symb.* Cl + 2 Cu; *Eq. by W.* 98.9 = Cl 35.5 + 63.4 Cu). This compound may be procured by exposing copper-filings (or a plate of copper) to the action of the green solution of the hydrochlorate in a well stopped bottle filled with the liquid, shaking it frequently. The solution becomes gradually colourless, and crystals of the dichloride are deposited. It was formerly prepared under the name of *resin of copper* by exposing to heat two parts of corrosive sublimate and one of copper-filings intimately mixed. It remains when the chloride is exposed to heat. It may also be procured by the action of chloride of tin with chloride of copper. Dichloride of copper has a whitish or amber colour, fuses at a little below a red heat, and is insoluble in water. It is dissolved by the nitric and hydrochloric acids; from its solution in the latter it may be precipitated as a white powder by water. Potassa precipitates dinoxide of copper.

1138. When exposed to air and moisture, it absorbs oxygen, and passes into a compound of oxide of copper and chloride of copper, which has a green colour. The same substance may be formed by the action of hydrochloric acid and air on sheet-copper partly immersed in the acid. It is known by the name of *Brunswick green.*

1139. The dichloride in union with water (or hydrochlorate of the dinoxide), is found native; formerly it was termed *sub muriate of copper.*

326   ZINC.

CHAP. IV.—ZINC (commonly called SPELTER).

Symb. Z. Eq. by W. 32.3. Sp. gr. 6.8 to 7.1. It fuses at about 773°. At low temperatures, and near its fusing point, zinc is brittle, but is malleable and ductile at about 300°. It is vaporized by a white or full red-heat. By cooling the fused metal slowly, it may be procured in prismatic crystals.

1140. Mix 500 grains of the oxide of zinc with 100 of charcoal, make the mixture into a paste with oil, and expose it to a bright red heat in a furnace. The carbonaceous matter combines with the oxygen of the oxide, forming carbonic acid or carbonic oxide, and metallic zinc is at the same time volatilized, burning with a fine bluish-green-coloured flame, and being again converted into oxide of zinc. Hence the impossibility of obtaining zinc in the metallic form by the usual process for reducing a metallic oxide. In manufactories, the pots or crucibles, containing the mixture from which it is procured, are closed at the top, and a tube open at both ends is made to pass through the bottom; the metallic zinc and carbonic acid disengaged enter at the extremity of the tube within the crucible, and passes out by the other extremity, to which another tube is fitted when the zinc is fit for being collected, condensing it, and allowing it to drop into a tub of water which is placed below.

1141. Metallic zinc is not found native. It is procured from two of its ores, CALAMINE (carbonate of zinc), and ZINC BLENDE (sulphuret of zinc). The calamine is sometimes roasted first; and the sulphuret is always roasted, in a reverberatory furnace, by which it is oxidized. The ore is then mixed with small coal or other carbonaceous matters in a covered pot or crucible, and heated, when the metallic zinc is separated, and vaporized by the heat. The vapour is conducted from the crucible by an iron-tube as described above, and the condensed zinc drops into water. The first portions are rejected, frequently containing cadmium and arsenic, which is known by the vapour being brown when set fire to. When it burns blue, the metal is purer, and is then condensed.

1142. The zinc thus procured is still impure, containing iron,

copper, lead, arsenic, cadmium, sulphur, carbon.   It may be
partly purified by redistillation in an earthen retort, exposing it
to a white heat, and condensing the vapour in a receiver con-
taining water.   The vapour that comes over first should be al-
lowed to escape, as it will contain the arsenic and cadmium.
The following process is also recommended.   Dissolve the purest
common zinc in diluted sulphuric acid, place a piece of metallic
zinc in it and leave them for a week or two ; then filter the so-
lution to separate any impurities which the acid may leave un-
dissolved, which appear as a dark powder.   Then precipitate car-
bonate of zinc by adding carbonate of potassa to the solution of
the sulphate, and after washing the carbonate well, reduce it by
charcoal in a retort heated in a furnace, collecting the zinc that
distills over as before.

1143.   When zinc is required in small fragments, it may be
easily obtained by melting it in an iron ladle and dropping it
into water.   See par. 55.   Though classed among the brittle
metals, it cannot be easily broken into small pieces by a hammer.

1144.   Zinc has a white colour, with a tinge of blue, and a highly
crystalline texture.   This metal is scarcely oxidated, or at least
with extreme slowness, when exposed to the air.   Its lustre is
tarnished, but excepting an extremely thin film (of suboxide, or
oxide mixed with metallic zinc), there is no oxidation.   Under
water at ordinary temperatures, if exposed to air, it is also
slowly oxidated.   It readily oxidates in air or water at a high
temperature.   In air it burns with a bluish-white flame, taking
fire, according to Daniell, at 941°.   Zinc is dissolved by acetic
acid.   It is quickly dissolved by nitric, hydrochloric, and sul-
phuric acids, hydrogen gas being evolved in the two latter cases ;
and a little zinc is said to be carried over in union with the hy-
drogen.   Strong sulphuric acid does not act upon it without the
aid of heat.   Zinc precipitates many metals from their solutions,
but is not itself precipitated by any other metal.

1145. OXIDE OF ZINC *(Symb.* OZ *or* ·Z ; *Eq. by* W. 40.3= O.8
+ 32.3 Z.).   This is the only compound of oxygen and zinc re-
garding which we possess any precise knowledge.   It may be
procured by the direct combination of its elements, by exposing
the carbonate to a red heat, or by precipitation from a solution
of the sulphate by an alkali.   It is white when cold, when heated

intensely it becomes yellow, but is white again when cool. It is insoluble in water, but is dissolved by strong ammonia.

1146. Put half an ounce of zinc into a crucible capable of containing eight or nine ounces of water, and expose it to a good red heat in a furnace or open fire. A crust of oxide soon gathers on its surface, and in a short time, part of the metallic zinc begins to be volatilized, burning with a rich bluish-green flame ; if it be then removed from the fire, inclining the crucible to one side, and if the oxide as the surface be removed from time to time as it is formed, a considerable quantity may be obtained ; a portion of the oxide is carried up mechanically by the current of hot air arising from the crucible, and has usually the appearance of very fine wool. This method of forming OXIDE of ZINC is one of the pharmaceutical processes for preparing this substance. Procured in this manner, it is termed flowers of zinc, philosopher's wool, &c.

1147. Another method of obtaining oxide of zinc, is, by adding a solution of potassa, soda, or ammonia, to a saturated solution of the sulphate of zinc, diluted with about fifteen times its bulk of water. Care must be taken not to add an excess of any of the precipitants, as it would redissolve the precipitated oxide. The best method of proceeding, when the quantity of alkali in a given weight of the solution employed is not known, is to add small quantities at a time, taking out a little of the clear solution at the top with a pipette, after shaking the mixture well and allowing it to remain at rest for a short time, and testing this by itself with a little of the alkaline solution ; if any precipitate be then thrown down, more alkali must be added, but if none appear, this shews that all the oxide has been already precipitated. A *hydrated oxide* is thus thrown down, which may be deprived of water by a red heat.

1148. Zinc is easily distinguished from any of the preceding metals, when in solution, by the white precipitate which it gives when a current of hydrosulphuric acid gas is transmitted through the liquid. Solutions of the hydrosulphate of ammonia, and the hydriodate or ferrocyanate of potassa, also give a white precipitate. Galls give no precipitate. Potassa and ammonia precipitate the oxide, as a bulky white powder, and the precipitate is redissolved by an excess of the precipitant.

1149. NITRATE OF ZINC may be obtained, by pouring two parts by weight of nitric acid, diluted with five or six times its weight of water, on one part of metallic zinc, evaporating the solution till a pellicle appears on its surface. It crystallizes in four-sided prisms. If the nitric acid be diluted with a very small quantity of water, as half its bulk, a very violent reaction takes place, and a large quantity of gaseous matter is disengaged. The nitrate is very deliquescent, and soluble in both water and alcohol. The crystals contain about six equivalents of water.

1150. SULPHURET OF ZINC. This is the native mineral—*zinc blende.* It may be procured by heating a mixture of oxide of zinc and sulphur in a covered crucible, or by heating the hydrate of sulphuret of zinc precipitated by hydrosulphuric acid.

1151. SULPHATE OF ZINC (white vitriol) is easily procured in crystals, by evaporating the solution that remains in the preparation of hydrogen gas by zinc, water, and sulphuric acid (51, page 17), after it has been digested for a short time with an excess of zinc. It crystallizes in right rhombic prisms, transparent and colourless. In the crystals, every equivalent of the sulphate (80.4) is combined with seven equivalents of water (63). They are soluble in two and a half parts of water at 60°, and are dissolved in large quantity by boiling water. It is easily fused, and soon loses its water of crystallization. By a very high temperature, the acid is entirely expelled. It reddens the vegetable blues.

1152. For use in the arts, this salt is prepared from the native sulphuret, *zinc blende,* by roasting it, extracting the soluble parts in water, evaporating, and crystallizing. Prepared in this manner, it contains iron and other metals. These may be removed by dissolving it in water, and putting zinc filings into the liquid. These precipitate the other metals, and the sulphate is separated in solution by filtration.

1153. CARBONATE OF ZINC and Sulphate of Potassa are formed, when a solution of the carbonate of potassa is added to a solution of the sulphate of zinc, a mutual decomposition taking place. The carbonate, being insoluble, is precipitated as a white powder, and the sulphate of potassa remains in solution. The salts should be dissolved separately in eight or nine times their weight of water, that there may be sufficient to retain the sulphate of potassa in solution when they have been mixed

together ; 69.32 parts of the carbonate of potassa are required for the decomposition of 143.4 of the crystallized sulphate. The carbonate thus formed contains some water. *Calamine* is a carbonate of zinc.

1154. ACETATE OF ZINC may be obtained, by digesting metallic zinc or the oxide in acetic acid, and concentrating the solution by evaporation, when, it is deposited in small crystals. It may also be formed, by mixing a solution of the acetate of lead with a solution of the sulphate of zinc, a double decomposition taking place in the manner represented in the diagram.

Fig. 202.

Before Decomposition.   *After Decomposition.*

Sulphate of	Oxide of Zinc	40.3	91.78 Acetate of Zinc.
Zinc	Sulphuric Acid	40.1	
Acetate of	Acetic Acid	51.48	
Lead	Oxide of Lead	111.7	151.8 Sulphate of Lead.

The sulphate of lead, being insoluble, is precipitated, and the acetate of zinc remains in solution. As both salts contain water of crystallization, in the form in which they are usually met, allowance must be made for this in weighing out the materials. The solution of the acetate of the Edinburgh Pharmacopœia is prepared, by mixing 60 grains of the sulphate of zinc with 80 of the acetate of lead, dissolving each previously in ten ounces of distilled water, and filtering the liquid afterwards to separate the sulphate of lead.

1155. The acetate of zinc crystallizes in rhomboidal plates with a shining lustre. The crystals contain a large quantity (about seven eqs.) of water. It is extremely soluble in water ; and has a bitter and somewhat metallic taste.

1156. CHLORIDE OF ZINC may be obtained in solution (hydrochlorate), by mixing hydrochloric acid and zinc in a glass vessel, diluting the acid with a third of its bulk of water ; hydrogen gas is disengaged. By evaporating to dryness and heating to redness in a glass-tube, dry chloride is procured. It is formed when filings of zinc are thrown into chlorine gas. It was formerly obtained by heating a mixture of zinc-filings and corrosive sublimate, and termed *butter of zinc.* It is deliquescent, and fuses at a temperature above 212°. It is somewhat soft even at ordinary temperatures.

CHAP. V.—ANTIMONY.

Symb. Sb. *Eq. by W.* 64.6. *Sp. gr.* 6.7. *It melts at* 810°, *and is volatilized by an intense heat.*

1157. Mix 400 grains of nitre with 800 of cream of tartar, and 1200 of the sesquisulphuret of antimony (the common sulphuret), all reduced previously to powder, and throw the mixture, in small quantities at a time, into a red-hot crucible, capable of containing at least 12 or 14 ounces of water. A rapid deflagration takes place, a large quantity of fumes are disengaged, and metallic antimony is found at the bottom of the crucible ; after the mixture is completely fused, allow it to rest in one position till it becomes cold, before taking the metal out. If the materials should not fuse as the deflagration takes place, the crucible must be returned to the furnace till the mass that remains becomes quite liquid. On the large scale crude tartar is employed, instead of cream of tartar.

1158. In this process, the potassa of the nitre and cream of tartar is fused, and attracts the sulphur of the sesquisulphuret, the metallic antimony being at the same time melted, and falling through the saline matter that floats above. It is evident that if the temperature be not sufficient to render the whole completely fluid, instead of obtaining a large button of metallic antimony at the bottom, it will be diffused through the mass in minute globules, which will not be easily separated. The nitric acid of the nitre assists the reduction, by oxygenating the carbonaceous matter of the tartaric acid and part of the sulphur of the sesquisulphuret of antimony.

1159. Another method by which metallic antimony is often prepared from the sesquisulphuret, consists in fusing it along with iron-filings, and adding a small quantity of nitre. For this purpose, 800 grains of the sulphuret may be mixed with 400 of iron-filings, exposed to a red-heat in a crucible, which need not be so large as the one required for the preceding process, and 200 grains of nitre must be added when the mixture is fused. The sulphur combines with the iron, forming sulphuret of iron, which is melted by the heat, and the potassa of the nitre ren-

ders the whole more liquid, the metallic antimony collecting at the bottom of the crucible as before. After the nitre is added, the mixture should be stirred with an iron rod before taking it from the fire. The nitric acid is completely decomposed.

1160. Instead of leaving the materials in the crucible, they may be poured out into an iron plate, which should be heated previously, to render it completely dry. A small mould may be easily made by folding a piece of sheet-iron into the form of a cone, or a red-hot old crucible may be used, which can be broken subsequently, so as to shew the position of the button of antimony below the flux.

1161. In both cases, the heat must never be continued longer than may be necessary to render the mixture liquid, as the antimony soon begins to be dissipated, burning with a bluish-white flame.

1162. The antimony thus procured is not perfectly pure. The greater part of the impurities may be removed by dissolving the metallic antimony in nitro-muriatic acid, and throwing the solution into water. A white powder will be precipitated containing the antimony. When this white powder is well washed, dried, mixed with twice its weight of tartar, and exposed to heat, until fused, in a covered crucible, a button of very pure metallic antimony is obtained. Dr Thomson recommends the antimony to be purified by reducing it to a fine powder, mixing it with its own weight of antimonic acid, and fusing it in a crucible. The impurities are oxidized by the oxygen of the antimonic acid, and pure antimony is left.

1163. Antimony is a brittle metal, readily reduced to powder in a mortar. It has a white colour, with a tinge of blue, considerable lustre, and a laminated crystalline texture. It may be crystallized easily by melting it, and cooling very slowly.

1164. Its lustre is tarnished by exposure to air and moisture, or by being kept under water. By long exposure, a dark film forms on its surface, being partly oxidated. But the oxidation goes on with extreme slowness. It is quickly oxidated by watery vapour passed over it at a red heat. When strongly heated in contact with air, it oxidates, the oxide rises as a white vapour, which may be collected by condensing it on cold bodies, and then appears in white, needle-shaped crystals, termed *argentine flowers of antimony*. These are sesquioxide of antimony.

1165. Expose two or three hundred grains of metallic antimony to a bright-red heat, in a crucible placed in a furnace; the blue flame with which it burns will be seen very distinctly, and a large quantity of white fumes are produced, formed by the combination of the antimony with the oxygen of the air. If the melted antimony be poured out of the crucible at this high temperature, from a height of 10 or 12 feet, and allowed to fall upon a stone-floor, it instantly divides into an infinite number of minute globules, all of which run from the part on which it falls, like radii from a common centre, still burning, and leaving a black mark as they roll along, lined on both sides with a white smoke, and producing a very large quantity of fumes.

1166, TERDINOXIDE or SESQUIOXIDE, formerly called OXIDE, OR PROTOXIDE OF ANTIMONY. *Symb.* O^3Sb^2, or $4Sb^2$. *Eq. by W.* $153.2 = 0.24 + 129.2$ Sb. This compound may be prepared by several different processes. The Dublin College recommends it to be prepared by throwing a solution of the sesquichloride (or hydrochlorate) into a large quantity of water; but in this case, it is a subhydrochlorate that is precipitated, the sesquioxide retaining a small portion of hydrochloric acid; according to Mr Phillips, one equivalent of acid is united with nine of the oxide. This precipitate was formerly termed *powder of algaroth*. It is sometimes termed an *oxychloride*, being regarded as composed of sesquioxide with a small quantity of sesquichloride.

1167. To get the whole of the oxide precipitated (a little remaining in solution, when water alone is used) and free from hydrochloric acid, we must pour the hydrochlorate into a solution of potassa, taking care to have a slight excess of alkali; the sesquioxide is precipitated in the form of a white bulky powder, which must be washed repeatedly with water, and then dried. In this case, the alkali unites with the acid, forming hydrochlorate of potassa, which remains in solution. For many purposes, the subhydrochlorate, precipitated by water alone, does very well.

1168. The small portion of hydrochloric acid in union with the precipitate formed from the hydrochlorate by water, may be removed by washing the precipitate, and boiling it in a solution of carbonate of potassa or of soda. On washing with water and filtering, the pure sesquioxide is procured.

1169. Sesquioxide of antimony is precipitated when an alkali

or alkaline carbonate is added to a solution of tartar emetic. The precipitate should be washed well with hot water.

1170. It may also be procured by heating the sulphate of antimony (1182) with a weak solution of potassa, washing the remainder with hot water, and drying. The sulphate, thrown into water, yields a subsulphate, sometimes used as sesquioxide.

1171. The matter condensed from the fumes formed during the combustion of antimony is sesquioxide (1164).

1172. The sesquioxide of antimony occurs native, commonly called *oxide of antimony.*

1173. Sesquioxide of antimony is white when precipitated, but becomes yellow when heated. It is fused by a low red-heat, and is vaporized by a full red-heat. The fused oxide becomes a grey crystalline solid on cooling. By heat in contact with air, it passes into antimonious acid. It is the base of the salts of antimony. These are in general insoluble (except tartar emetic), or are readily decomposed by water, the sesquioxide having a feeble attraction for acids, so that the affinity between the water and the acid causes the separation of the sesquioxide.

1174. Mix 1000 grains of the sesquisulphuret of antimony with an equal weight of nitre, put the mixture into a cone of paper, and touch it at the top with a red-hot iron wire, after placing it on an earthen dish or iron plate. A rapid deflagration immediately takes place, a large quantity of fumes are disengaged, and a dark brown substance remains, mixed with a quantity of saline matter, the latter being composed principally of the potassa of the nitre. The nitric acid affords oxygen to the greater part of the sulphuret, the sulphur being acidified, while the antimony is converted into a sesquioxide. By reducing it to a fine powder, and washing it repeatedly with boiling water, all the saline matter is dissolved, and the sesquioxide is obtained, still mixed, however, with a portion of the sesquisulphuret of antimony, which is not decomposed. In this state, it is employed in the process of the Edinburgh College, for the preparation of tartar emetic, and was formerly called *crocus of antimony.* This and the glass of antimony (1176) are sometimes termed *oxysulphuret of antimony.*

1175. In the present process of the London College, the materials for forming the crocus are mixed with a little hydro-

chloric acid (about an ounce to the pound of materials), before they are ignited.

1176. A SESQUIOXIDE (or oxysulphuret) of antimony may also be obtained, by exposing the sesquisulphuret in powder to heat in the open air, the sulphur being converted into sulphurous acid, and escaping in the gaseous form. By exposing it to a stronger heat in a crucible, it is fused into a glass, commonly called *glass of antimony*, which has a reddish colour, from the presence of a little undecomposed sesquisulphuret, and is quite transparent. It combines, at the same time, with part of the earthy matter of the crucible in which it is fused, silica being always detected in it, though the quantity varies considerably. Glass of antimony was used in the former process of the London College, in the preparation of tartar emetic.

1177. ANTIMONIOUS ACID (Deutoxide of Antimony). When the sesquioxide of antimony is exposed to a red-heat in contact with air, it absorbs more oxygen and becomes antimonious acid. This compound may be formed also by continuing the roasting of the sesquisulphuret after the sulphur has been expelled (1176). When antimonic acid is exposed to a red-heat, part of the oxygen is expelled and antimonious acid remains. It is represented as being composed of two eqs. of antimony and four of oxygen. It combines with alkalis by fusing them together, forming with potassa a soluble compound, from the solution of which it is precipitated as a hydrate by the strong acids. It reddens litmus

1178. ANTIMONIC ACID (or peroxide of antimony). *Symb.* $O^5 + Sb^2$, or $∴Sb^2$. *Eq. by W.* 169.2 = 0.40 + 129.2 Sb. To prepare this compound, dissolve metallic antimony in aqua-regia, dissipate any excess of acid by heat, and throw the solution into water. Antimonic acid is precipitated. Or, add metallic antimony in fine powder, or the pure sesquioxide, to hot nitric acid, in a green glass-flask or evaporating basin, evaporating to dryness, and heating what remains to a temperature of 500° or 600°, to expel any water which it may still contain. The temperature must not be increased beyond this, otherwise part of its oxygen will be disengaged ; 100 grains of metallic antimony and 1000 of acid will be a sufficient quantity of materials to shew the nature of the process, and the appearance of the antimonic acid. It may be obtained also by deflagrating metallic anti-

mony in powder with five or six times its weight of nitre, washing the residue with water, and then with hydrochloric acid, and drying and heating it as before. It reddens litmus paper, and forms salts with the alkalis.

1179. Pulvis Antimonialis, or Oxide of Antimony with Phosphate of Lime, which was introduced as a substitute for James's powder, is prepared from a mixture of equal weights of hartshorn shavings and sesquisulphuret of antimony. The method recommended is, to expose the mixture to heat in a shallow iron or earthen vessel till it assumes an ash-grey colour, when it may be considered as composed of sesquioxide of antimony and phosphate of lime, the latter being derived from the hartshorn shavings, while all the animal matter is burnt away. It is then to be reduced to powder, and put into a crucible, which may be coated with clay, and wrapped round with iron wire, luting on a cover, but leaving a small opening at the side ; the crucible is then put into a furnace, and exposed to a red-heat for two hours, after which it may be removed.

This is the process which is recommended by the Edinburgh and Dublin Colleges ; the London directs two parts of hartshorn shavings to be used along with one of the sesquisulphuret of antimony.

1180. According to the analyses of Pearson, Brande, and Phillips, it consists of antimonious acid and phosphate of lime, the proportion of these ingredients varying in different specimens. Dr Douglas Maclagan has recently made a more minute and elaborate examination of this important compound, and proved the presence of the sesquioxide of antimony. This explains the circumstance that it sometimes proves an active medicine, while in other cases it has been found to be perfectly inert, the antimonious acid having little or no action on the animal economy.

Salts of Antimony ; Sulphuret and Chloride of Antimony.

1181. None of the salts of antimony are so important as the sulphate, the hydrochlorate (sesquichloride), and the tartrate of antimony and potassa, or tartar emetic.

1182. A compound of sulphuric acid and sesquioxide of antimony is easily prepared, by boiling metallic antimony, reduced to a very fine powder, with thrice its weight of sulphuric acid in an iron vessel, heating the mixture over an open fire, and stirring it frequently with an iron rod till it becomes quite dry. In this process, the metallic antimony attracts oxygen from part of the sulphuric acid, and sulphurous acid gas is disengaged, the sesquioxide of antimony that is formed combining with part of the sulphuric acid that is not decomposed ; the excess of acid is expelled by the heat.

Mr Phillips has proposed to prepare tartar emetic with the sesquioxide, or rather the subsulphate, which is obtained on throwing the sulphate into a large quantity of water.

1183. SESQUISULPHURET of ANTIMONY occurs native, and is the ore of antimony from which the metal is usually procured. It was called *stibium* formerly, and is still often spoken of as *antimony*, or *crude antimony* ; the metal being termed *regulus of antimony*. It is separated from the stony matter with which it is mixed by exposing the ore to heat in a crucible with an aperture in the bottom, another crucible being placed below it, to receive the sesquisulphuret as it flows out. It is better always to purchase it in the form in which it is taken out of the crucible, the pounded sesquisulphuret being frequently adulterated with a quantity of earthy matter ; I have met with it containing at least a third part of its weight of earthy substances, the greater part of which was silica.

1184. By transmitting a stream of hydrosulphuric acid gas through a solution of tartar emetic, or of any other solutions of antimony, a copious precipitate of a bright orange colour is thrown down, which is composed of sesquisulphuret of antimony and water, the hydrogen of the hydrosulphuric acid combining with the oxygen of the sesquioxide, and the sulphur with the metallic antimony. The water may be expelled by heat, when the sesquisulphuret assumes a dark colour. By fusing sulphur and antimony together, a sesquisulphuret is formed.

1185. To prepare the precipitated sulphuret of the Edinburgh and London Colleges, the common sesquisulphuret is boiled with a solution of caustic potassa for an hour or two, in an iron vessel, over a common fire, adding water from time to time, that there may be the same measure of liquid on removing it from the fire as

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at first. It is filtered immediately through a double linen cloth, and sulphuric acid, previously diluted with six or seven parts of water, is dropped into the filtered liquid (while still warm) as long as any precipitation takes place.

1186. In this process, a portion of water and part at least of the sesquisulphuret are decomposed, the hydrogen combining with the sulphur, and the oxygen with the metallic antimony, forming hydrosulphuric acid and sesquioxide of antimony, both of which are dissolved, so that the solution may be regarded as a compound of hydrosulphuric acid, sesquioxide of antimony, and undecomposed sesquisulphuret with potassa. On adding the diluted acid, sulphate of potassa is formed, which remains in solution, and the sesquioxide of antimony is precipitated along with sesquisulphuret of antimony. Such is the general nature of the reaction which is supposed to take place ; but the determination of the precise constitution of this precipitate is involved in considerable difficulties, and it has been variously estimated by different experimenters.

1187. The proportions recommended by the Edinburgh College are four parts by weight of their solution of potassa, three of water, and two of the sesquisulphuret of antimony. To prepare a small quantity of the solution of sesquisulphuret of antimony in a solution of potassa, equal weights of sesquisulphuret of antimony and fused potassa may be taken and boiled with eight times their weight of water in an iron goblet ; an excess of the sesquisulphuret does no harm, as it is not dissolved, and affords a larger surface for the action of the potassa and the water.

1188. If the solution be allowed to cool without the addition of any acid, a considerable quantity of a precipitate of a reddish-yellow or reddish-orange colour is gradually deposited, the solution of potassa not being able to dissolve so much when it is cold ; it is called *Kermes mineral.*—See Brewster's Journal, New Series, vol. iii. p. 356. It has been regarded as a hydrated sesquisulphuret by Berzelius, but generally contains a little sesquioxide and potassa.

1189. If the liquid be then filtered, and diluted sulphuric acid be added, an additional precipitate is thrown down, more of a golden-yellow colour than any of the other precipitates. It is usually termed the *Golden Sulphuret of Antimony.* This is said to contain no potassa, and more sesquioxide of antimony.

1190. Tartrate of Antimony and Potassa, or Tartar Emetic, is prepared by boiling together equal weights of cream of tartar and sesquioxide of antimony in four times their weight of water, filtering the solution afterwards, and evaporating the clear liquid till a pellicle appears on its surface. It crystallizes in octohedrons with a rhombic base. Both the cream of tartar and the sesquioxide of antimony are to be reduced to a fine powder before they are mixed, and the water should be made to boil before they are put in; the materials must be boiled for at least half an hour.

1191. The sesquioxide obtained by precipitation from the hydrochlorate is perhaps preferable to that prepared in any of the other methods, as it requires little or no trouble to reduce it to a minute state of division ; the *glass of antimony* is not so easily reduced to an impalpable powder. I have frequently tried the sesquioxide prepared from the sulphate according to Mr Phillips process ; it does very well, if proper attention be paid to the pounding of the metallic antimony before digesting it in the acid, and to the separation of the subsulphate from any metallic antimony that may not have been oxidated.

1192. Though equal weights of the sesquioxide and cream of tartar are recommended to be used, the whole of the sesquioxide is not dissolved. One equivalent of cream of tartar, 198.16, which contains 18 parts, or two equivalents, of water, combines with two equivalents of the sesquioxide of antimony to form tartar emetic, and the crystals contain three equivalents of water ; the chemical equivalent of the crystallized tartrate must accordingly be 360.36. (Phillips.)

Tartaric Acid (66.48 × 2)	132.96
Potassa	47.2
Sesquioxide of Antimony	153.2
Water (9 × 3) . . . . ,	27.
	360.36

1193. When its solution in water is kept for some time, it is decomposed ; Dr J. Davy has found, that, when it is exposed for some weeks to the rays of the sun, it is rendered turbid, and a portion of antimonic acid is precipitated.

1194. Tartar emetic is soluble in a little less than three times its weight of boiling water, and in fifteen parts of cold water.

Acids, alkalis, alkaline earths, and a great many vegetable in-
fusions and decoctions, decompose it.   It is slightly efflorescent.

1195. Add some nitric, sulphuric, or hydrochloric acid, to a
strong solution of tartar emetic ; a copious precipitate is thrown
down, consisting of cream of tartar and insoluble sesquioxide
or sesquichloride of antimony.

1196. To a similar solution, add a small quantity of a solu-
tion of potassa, soda, or ammonia.   The alkali combines with
the tartaric acid, and sesquioxide of antimony is precipitated,
which may be redissolved by an excess of potassa.   A strong
fresh infusion of galls gives a whitish-yellow precipitate with
tartar emetic.

1197. A precipitate is also thrown down by lime water, and
by a solution of baryta ; it consists of sesquioxide of antimony
and tartrate of lime or baryta.

1198. When a solution of the hydrosulphate of ammonia, or
of any other soluble hydrosulphate, is added to a solution of
tartar emetic, or of any other salt of antimony, a copious pre-
cipitate is thrown down, similar to what is obtained on adding
sulphuric acid to the solution of the hydrosulphate of antimony
and potassa, the same reaction taking place between the hydro-
sulphuric acid and the sesquioxide of antimony that has been
already described (1186).

1199. When too large a dose of this salt has been given, the
best antidotes are a solution of hydrosulphuric acid, solutions of
the hydrosulphates, and infusions of cinchona bark, galls, or tea.
In a case treated by Dr Duncan, where a dose sufficient to have
caused death had been taken, he gave a solution of the *hepar
sulphuris* with complete success.

1200. The most delicate test of tartar emetic in solution is
hydrosulphuric acid, which produces a characteristic reddish-
orange precipitate, even in solutions containing a very minute
quantity of this salt.   The student should now transmit a stream
of hydrosulphuric acid gas through solutions of tartar emetic of
different strengths, and mixed with a number of other liquids,
as milk, tea, porter, &c., till he becomes familiar with the ap-
pearance it presents.

1201. In applying this test for the detection of antimony in
mixed solutions, where it may be suspected to have been ad-
ministered as a poison, Dr Turner recommends the liquid to

be boiled for a few minutes with a drachm or two of hydrochloric and tartaric acids before filtration ; the tartaric acid retains the antimony in solution, and dissolves any of the sesquioxide that may have been precipitated by an infusion of tea, bark, or galls, while the hydrochloric acid promotes the coagulation of any caseous matter that may be present. The hydrosulphuric acid gas is then to be transmitted through the liquid. The sulphuret is then to be dried, and put into a small glass tube, about three inches long and a quarter of an inch in diameter, transmitting a stream of hydrogen gas slowly over it by connecting one end of the tube by a cork with an apparatus from which this gas is disengaged, and adapting to the open end a bent tube, the other extremity of which is made to dip under water. The tube must be heated by a spirit-lamp at the part where the sulphuret is placed, and great care must be taken not to apply the heat till the air of the apparatus has been completely expelled, to prevent an explosion taking place. Towards the end of the process, the temperature ought to be increased to bright redness, by directing the flame of the lamp with the blowpipe upon the part of the tube immediately below the sulphuret.

1202. By this process the sulphuret is completely decomposed, the hydrogen combining with the sulphur and forming hydrosulphuric acid, while the metallic antimony is melted, and forms a film upon the internal surface of the glass, or collects in minute globules. A light green glass tube should always be preferred, containing no lead, and being less easily softened.

1203. Should the film of metal be indistinct, it should be redissolved by the aid of heat in a little aqua-regia, precipitated by water, the precipitate be again dissolved by tartaric acid, and the liquid again tested by passing hydrosulphuric acid gas through it.

1204. Throw some tartar emetic upon some red hot cinders ; the tartaric acid will be completely decomposed, the carbon combining with part of the oxygen of the oxide, while metallic antimony is set at liberty, and appears in the form of minute globules. When exposed to a red-heat excluded from access of air, a substance possessed of pyrophoric properties remains.

1205. By exposing a very small quantity to heat on charcoal before the flame of the blowpipe, the metallic antimony is seen

more distinctly, and white fumes of the oxide of antimony are at the same time produced.

1206. The antimony liberated on decomposing tartar emetic is always combined with potassium, produced by the charcoal of the tartaric acid decomposing the potassa and sesquioxide of antimony at the same time.

1207. Tartar emetic is frequently contaminated with cream of tartar. The cream of tartar may be detected by adding a little carbonate of soda to a hot solution. If the precipitate be redissolved, cream of tartar is present. It should be procured in the form of crystals, not in powder.

1208. To prepare the SESQUICHLORIDE OF ANTIMONY according to the process of the Dublin College, 20 parts of the sesquisulphuret of antimony (in fine powder) are to be digested in a glass vessel with 100 parts of hydrochloric acid, with a heat gradually increased till all effervescence ceases, and then to be boiled for an hour. The solution always contains an excess of acid, and should be filtered when cold through a double linen cloth, or allowed to remain at rest till all the particles of sesquisulphuret of antimony that have not been acted upon shall have been deposited.

1209. In preparing this compound, much hydrosulphuric acid is evolved, the production of which arises from the combination of the sulphur of the sesquisulphuret with the hydrogen of the hydrochloric acid. But if the compound consist of hydrochloric acid and sesquioxide of antimony, water must necessarily be decomposed as it is formed, the oxygen uniting with the antimony, and the hydrogen combining with the sulphur to form the hydrosulphuric acid.

1210. One part of nitric acid is recommended to be added, when the action of the hydrochloric acid shall have ceased, in order that it may decompose any hydrosulphuric acid that may not be expelled, and prevent it from reacting on the oxide procured on pouring the sesquichloride into water.

1211. The sesquichloride may be procured free from water (which is always associated with it when it is prepared by hydrochloric acid), by pouring metallic antimony in fine powder into a bottle of chlorine gas. The best method of proceeding is to take a glass-funnel and put a little paper round the tube, if it should not fit closely to the neck of the bottle containing the

chlorine ; the antimony should then be thrown in, taking very small quantities at a time, and keeping the funnel sufficiently high to allow the metal to fall through as much of the chlorine as possible ; the antimony takes fire whenever it comes into contact with the chlorine.

1212. A more convenient method of preparing the sesquichloride of antimony consists in mixing this metal with three times its weight of the bichloride of mercury, and heating the mixture in a glass-retort by a chauffer. A receiver must be fitted to the retort to condense the sesquichloride that is distilled over. The metallic antimony combines with all the chlorine, and the mercury is disengaged.

It is usually called *butter of antimony*, from its soft consistence ; it melts when exposed to a gentle heat, and assumes a crystalline texture by cooling. It is decomposed by a large quantity of water in the same manner as its solution (1166).

1213. The BICHLORIDE OF ANTIMONY has been formed by the action of hydrochloric and hydrated antimonic acids. Another chloride with still more chlorine has also been formed by Rose, by heating metallic antimony and passing dry chlorine over it.

CHAP. VI.—TIN. (STANNUM.)

Symb. Sn.   *Eq. by W.* 58.9.   *Sp. gr.* 7.29.   *It melts at* 442°,
and may be volatilized by a very intense heat.

1214. The ore from which this metal is procured is a compound of binoxide of tin and oxide of iron, commonly called *tin-stone.* The ore is found in veins, from which form of it, *block-tin* is extracted. It is also found in loose grains, scattered through the soil, termed *stream-tin,* and yielding a purer metal, called *grain-tin.* To extract the metal from the ore dug from the veins, it is ground, washed, by which a quantity of earthy impurities are separated, roasted in a reverberatory furnace, by which sulphur and arsenic are expelled, and then mixed with coal (or culm) and limestone, and again heated in a reverberatory furnace for a considerable time. The metallic tin is separated, and subsides through the fused mass. It is again melted, and kept fused for some time, by which a quantity of

impurities separate and rise to the surface, being then removed. The finer ore, *stream-tin*, is smelted with charcoal, in a sort of blast furnace. The grain-tin thus procured is said to be very pure, not containing 1-500th part of impurities, chiefly copper, arsenic, and iron.

1215. Mix 1200 grains of the oxide of tin with 100 grains of charcoal, 200 of carbonate of potassa, and 160 of dry carbonate of soda (free from water of crystallization), and expose the mixture to a good heat in a crucible placed in a furnace for twenty minutes. The carbon unites with the oxygen of the oxide, and metallic tin will be found in the crucible.

1216. When tin is required in a minute state of division, it is obtained easily in this condition by melting it and shaking it quickly in a wooden box, rubbed over with chalk in the inside. It may be procured also, but not so easily, by melting it in a ladle, and stirring it constantly with an iron pestle as it cools. An iron mortar does better than a ladle, and is more easily kept in a fixed position. The fine powder obtained by any of these methods should be separated from the larger particles by passing it through a sieve : these may be melted again, and reduced to powder as before. Tin may be granulated, like zinc, by pouring it when melted from a height into water.

1217. Tin has a fine white colour, like silver, and a very brilliant metallic lustre. It is comparatively a soft metal, possessing considerable malleability and even flexibility, and emits a peculiar crackling noise when bent. *Tin-foil* is about 1-1000th part of an inch in thickness. Tin is ductile, but possesses little tenacity, so that a fine wire breaks with a very small weight.

1218. Tin is tarnished, but in a very slight degree, by exposure to air ; and can scarcely be said to be oxidated by exposure to air or water at ordinary temperatures. At a red-heat, it decomposes water passed over it in vapour, with evolution of hydrogen. At its fusing point, it oxidates slowly in air, and at a white-heat it burns, oxidating rapidly.

1219. OXIDE (or PROTOXIDE) of TIN. *Symb.* OSn. or ·Sn. *Eq. by W.* $66.9 = 0.8 + 58.9$ Sn. This compound may be prepared by adding a solution of carbonate of soda to a newly prepared solution of chloride of tin. It is precipitated as a white hydrate, and may be procured anhydrous by washing with water, and heating it to near a red-heat out of access of air, being

placed in a retort filled with carbonic acid or hydrogen gas. It may also be procured by melting tin in an iron ladle, and exposing it freely to the air, taking care not to raise its temperature too high. A crust gathers on the surface of the tin, consisting of the oxide. The anhydrous oxide is of a grey or dark colour. It is sometimes termed *black oxide of tin.*

1220. Oxide of tin absorbs more oxygen, taking fire, and becomes binoxide, when raised to a red-heat (or even touched by a red-hot iron) in contact with air. It dissolves readily in the acids and fixed alkalis, but not in ammonia nor alkaline carbonates. In an alkaline solution, it is ultimately resolved into metallic tin which subsides; and binoxide which remains in solution. It has a great attraction for oxygen, and absorbs it from solutions of some metallic oxides, reducing them to a lower state of oxidation (as copper or iron), or to the metallic state (as mercury, silver, platinum).

1221. SESQUIOXIDE OF TIN. *Symb.* O^3Sn^2 or $\vdots Sn^2$. *Eq. by W.* $141.8 = 0.24 + 117.8$ Sn. This compound is procured by the action of hydrated peroxide of iron on chloride of tin in solution. The sesquioxide subsides. It is soluble in ammonia, and gives a purple precipitate with gold.

1222. BINOXIDE OF TIN (called also Peroxide of Tin). *Symb.* O^2Sn or $\vdots Sn$. *Eq. by W.* $74.9 = 0.16 + 58.9$ Sn. This compound occurs native, generally associated with oxide of iron. It may be prepared by exposing metallic tin to a full white-heat, putting it in a crucible placed in a furnace, and resting about an inch and a half above the branders. The tin takes fire, burns with a white flame, and becomes binoxide of tin, termed *flowers of tin* when formed in this manner.

1223. Put half an ounce of nitric acid into a deep glass, add about a drachm of water to it, and pour in two or three hundred grains of the powder of tin ; a violent effervescence takes place, and the metal probably attracts oxygen both from the acid and the water. Hydrogen and nitrogen gases, meeting in a nascent state, unite and form a portion of ammonia, which combines with a portion of nitric acid which is not decomposed, forming nitrate of ammonia. As white fumes are mixed with the large quantity of ruddy vapours of nitrous acid that are at the same time disengaged, it has been considered that they are produced by a portion of the nitrate of ammonia formed in this manner.

Considerable heat is evolved, and the tin is left in the form of a bulky white powder.—*hydrated binoxide of tin.* On washing this powder with water, and exposing it to a red heat, the water is expelled, and the anhydrous binoxide of tin remains, of a pale yellow colour.

1224. Binoxide of tin may also be procured by heating together tin-filings and binoxide (red oxide) of mercury.

1225. Anhydrous binoxide of tin, procured in any of the above modes, is insoluble in the acids, combining, however, with hydrochloric acid, and forming a compound which is soluble in water. It may be made to combine with glass, an *enamel* being then formed.

1226. Binoxide of tin is precipitated as a bulky hydrate when an alkali or alkaline carbonate is added to a solution of bichloride of tin. In this state it is readily dissolved by diluted nitric, sulphuric, or hydrochloric acids. It is soluble in ammonia and the other alkalis. It reddens litmus, and, combining with alkalis, is sometimes termed *stannic acid.* A precipitate of yellow bisulphuret of tin is formed, when its solution is decomposed by hydrosulphuric acid, or hydrosulphate of ammonia. The precipitate is soluble in potassa, or in an excess of the hydrosulphate of ammonia.

1227. Take a common tin-plate (which is in reality a plate of iron coated with tin) about a foot square, hold it over a chauffer, or before the fire, with a pair of pincers, till a drop of water allowed to fall upon its surface begins to boil immediately, and then wash one of its sides with a mixture of four parts by measure of water, one of nitric, and one of hydrochloric acid. Its surface will immediately assume a beautiful crystalline appearance, and by heating the plate at particular parts with the blowpipe, or exposing different parts to higher and lower temperatures, a great variety of figures may be produced, which will be seen better on washing it with water. The *moiree metallique*, or crystallized tin-plate as it is sometimes termed, of which a great number of hardware articles are now made, is prepared in this manner, and the various colours which it is made to assume are communicated by giving it a thin coating of different coloured varnishes. The tin-plates used for this purpose should have a good coating of metallic tin, otherwise most of the tin will be removed during the preparation of the

moirce, and nothing will remain but the iron below, which has a very dark colour.

1228. Salts of the oxide of tin may be recognised by the following characters :

1. They are white, and their solutions are colourless.

2. A solution of gold gives a brown, purple *(purple of Cassius)*, blue, green, or metallic precipitate, according to the proportions in which they are mixed, and the degree of concentration. (Buisson.)

3. Plates of lead and zinc often precipitate metallic tin.

4. A solution of the bichloride of mercury gives a dark-coloured precipitate.

5. Alkaline hydrosulphates give a dark brown-coloured precipitate.

6. Ferrocyanate of potassa gives a white precipitate.

7. They abstract oxygen from persalts, as those of copper, iron, mercury.

8. Ammonia gives a white precipitate, not soluble in excess of the alkali.

1229. With salts of the binoxide alkaline hydrosulphates give a yellow precipitate, and chloride of gold does not precipitate purple of Cassius.

1230. Tin combines with sulphur in various proportions. The BISULPHURET OF TIN was formerly known by the name of *aurum mosaicum* or *musivum*, or *mosaic gold*. This is procured by mixing two parts of sulphur, two of binoxide of tin, and one of sal-ammoniac, and heating them in a retort. It may also be procured by amalgamating 12 parts of tin with 6 of mercury, mixing the powdered amalgam with 7 parts of flowers of sulphur and 6 of sal-ammoniac, and heating the mass in a crucible or flask. It is procured by breaking the flask. It is in fine scales, of a golden yellow colour. It is used in the arts to furnish a kind of *bronze*, in the state of a powder termed bronze powder.

1231. The SULPHURET (SSn) is precipitated, of a dark colour, from solutions of the oxide or chloride of tin by hydrosulphuric acid or the hydrosulphate of ammonia. The BISULPHURET (S^2Sn) is thrown down of a yellow colour, by the same reagents, from solutions containing binoxide or bichloride of tin.

1232. CHLORIDE OF TIN (protochloride or protomuriate of tin). *Symb.* ClSn : *Eq. by W.* $94.4 = Cl\ 35.5 + 58.9\ Sn$. This

compound is procured by evaporating its solution to dryness, and fusing in a close vessel. It may also be formed by mixing together equal weights of granulated tin and the bichloride of mercury, and distilling till the mercury is expelled ; or by transmitting hydrochloric acid gas over tin heated strongly in a glass-tube. It is a grey-coloured solid, fused below a red-heat, and volatilized by a higher temperature.

1233. Chloride of tin in solution (hydrochlorate or muriate of tin) may be obtained by heating tin in twice its weight of hydrochloric acid. Hydrogen gas is disengaged, having an extremely fetid and disagreeable odour, partly owing to the presence of a little hydrochloric acid gas, partly to impurities in the tin, which are dissolved by the hydrogen. It is considered by some that a portion of the tin combines with the hydrogen. The chloride may be procured in crystals containing three equivalents of water, by evaporating a strong solution. These crystals are decomposed by heat or adding a large quantity of water ; oxide and chloride of tin being chiefly formed.

1234. The above proportions of tin and hydrochloric acid give the *protomuriate of tin,* so much employed by dyers and calico printers. It is a powerful deoxidating agent, and with this view is much used in calico-printing, as well as to furnish oxide of tin to act as a mordant to fix some colours. The chloride has a tendency to pass into bichloride, the metallic tin eliminated withdrawing oxygen from the oxide which it meets in solution.

1235. BICHLORIDE OF TIN (called also perchloride, permuriate). *Symb.* Cl^2Sn. *Eq. by W.* $129.9 = Cl\ 71 + 58.9\ Sn$. This compound may be obtained by distilling a mixture of granulated tin with three times its weight of bichloride of mercury—or 1 of mercury, 6 of tin, and 33 of the bichloride may be employed. The materials are to be exposed to a moderate heat in a glass-retort. A volatile colourless liquid condenses in the receiver, which attracts moisture from the air, and gives out fumes : it was formerly termed the *Fuming Liquor of Libavius.* This boils at 248°. With one-third part of water, it forms a solid hydrate ; dissolving in more water. It absorbs moisture from the air, and forms crystals.

1236. Bichloride of tin is also formed when the chloride is

exposed to heat in chlorine gas, or by heating the chloride very gently with the addition of a little nitric acid.

1237. This compound in solution, commonly termed *permuriate of tin*, may be procured by adding one part of tin, in small quantities at a time, to four of hydrochloric acid mixed with two of nitric acid. One part (or two) of water may be added to the mixed acids. A considerable quantity of gas is disengaged, and heat evolved during the solution of the tin. A solution of the chloride, exposed freely to the air, passes to bichloride ; or, the chloride may be combined with another equivalent of chlorine, by passing chlorine through it. The bichloride (permuriate) is much employed in dyeing and calico-printing, and is sometimes prepared for use in these arts by the action of granulated tin on dilute nitric acid and about an eighth of sal-ammoniac, or common salt, which furnishes the chlorine.

CHAP. VII.—BISMUTH.

Symb. Bi. *Eq. by* W. 71.5. *Sp. gr.* 9.8. *It melts at* 497°, *and is volatilized by a red-heat.*

1238. BISMUTH exists native, and also in union with oxygen, and with sulphur and arsenic. The bismuth of commerce is obtained from native bismuth-ore, melted for the purpose of separating the metal from the stony matter with which it is mixed. The bismuth thus procured contains a little sulphur, iron, and copper. It may be obtained pure by dissolving the common bismuth in nitric acid, pouring the solution into water, by which subnitrate of bismuth is precipitated, washing and drying the subnitrate, and heating it in a crucible with a little charcoal or black flux.

1239. Melt some bismuth in a crucible ; when the surface becomes solid, and while the greater part of the metal is still melted within, make a small hole in the middle, and invert the crucible till all the liquid metal has been poured out. On breaking into the hollow mass that is left, its internal surface will be found studded with crystals of metallic bismuth. Another method of proceeding is, to melt the bismuth in an iron ladle, cooling

the bottom by immersing it in cold water, before breaking the crust above, and taking care not to allow any water to fall upon the melted metal, lest some of it should be thrown about with explosive violence.

1240. Bismuth has a white colour with a tinge of red, and a high metallic lustre. It is of a crystalline texture, forming in parallelopipeds when prepared as described above. Its crystalline form is that of an octohedron. It is rather brittle when cold, and may be then reduced to powder in a mortar, but is somewhat malleable when heated. It is scarcely oxidated by exposure to air, but loses its lustre. It is acted on very slowly by the sulphuric or hydrochloric acids. Nitric acid quickly dissolves it, nitrate of oxide of bismuth being formed.

1241. OxIDE OF BISMUTH. *Symb.* OBi, or ·Bi. *Eq. by W* 79.5 = 0.8 + 71.5 Bi. This is best prepared by exposing the nitrate or subnitrate of bismuth to a red-heat. It is of a straw-yellow or yellowish-white colour. It is volatilized by a very high temperature. When fused, which takes place when it is heated to redness, it becomes an opaque brownish-yellow liquid, returning to a yellowish-glass when cool. It is the base of the salts of bismuth.

1242. Melt some bismuth in a crucible, and expose it freely to the air. A crust soon collects upon its surface, composed principally of oxide of bismuth. When bismuth is strongly heated in a furnace, it is volatilized and oxidated, burning with a bluish-white flame ; and yellow oxide of bismuth in powder is formed.

1243. There is a SESQUIOXIDE OF BISMUTH, prepared by fusing the hydrate of potassa and the oxide of bismuth.

1244. CHLORIDE OF BISMUTH may be formed by throwing the metal in fine powder into chlorine gas, the bismuth taking fire, and combining with the chlorine ; or by distilling a mixture of one part of bismuth and two of bichloride of mercury. It was formerly called *butter of bismuth.*

1245. NITRATE OF BISMUTH. This salt is prepared by dissolving metallic bismuth in nitric acid diluted with half its weight of water, until the acid will dissolve no more. The metal is quickly acted upon, and binoxide of nitrogen evolved. The nitrate may be procured in rhomboidal prisms, containing

three eqs. of water. It is decomposed by a red-heat (1241.) and by a large quantity of water (1247).

1246. The salts of bismuth are decomposed, when in solution, by a large quantity of water. Hydrosulphuric acid and solutions of the hydrosulphates give a dark-brown coloured precipitate. The ferrocyanate of potassa gives a white precipitate with a tinge of yellow. The oxide precipitated from its salts by water, or by solutions of the alkalis, is very easily decomposed by the blowpipe, when dried and heated on charcoal, a globule of metallic bismuth being obtained. It is distinguished easily by being very brittle, by its colour, and by decomposing nitric acid with effervescence. Fixed alkalis and their carbonates give a white precipitate, not dissolved by adding an excess of the precipitant. Galls give an orange-yellow precipitate

1247. The Subnitrate of Bismuth, commonly called *Magistry of Bismuth*, *Oxide of Bismuth*, is prepared by throwing a solution of the nitrate into a large quantity of water. It is immediately resolved into two salts, the subnitrate which is precipitated, and the supernitrate which remains in solution. According to Mr Phillips, the precipitate consists of one equivalent of nitric acid and three of the oxide.

1248. The nitrate employed for this preparation contains an excess of acid, according to the formula generally given for its preparation. It is procured by heating gently two parts of bismuth in fragments with five or six of nitric acid, diluted previously with half its bulk of water. Strong nitric acid acts with great violence on bismuth.

1249. Pour a little of the liquid that remains, after the precipitation of the subnitrate, into a glass, and transmit a stream of hydrosulphuric acid through it; the dark coloured precipitate of sulphuret of bismuth that immediately appears proves that there is still some bismuth in solution. If the nitrate do not contain an excess of acid, almost the whole of the oxide of bismuth is precipitated when the salt is thrown into a large quantity of water.

1250. To a solution of the nitrate of bismuth, add a solution of the tartrate of potassa, as long as any precipitation takes place; nitrate of potassa remains in solution, and Tartrate of Bismuth is precipitated, formerly known by the name of Pearl-White, and much employed as a cosmetic.

CHAP. VIII.—MANGANESE.

Symb. Mn. *Eq. by W.* 27.7. *Sp. gr.* 8. *Fused only by the highest heat of a smith's forge.*

1251. METALLIC manganese does not occur native. It has been procured in small grains by mixing the oxide with charcoal, making it into a ball with oil, and exposing it to the greatest heat of a smith's forge. The sides of the crucible must be lined previously with a stiff paste made of charcoal and oil. otherwise a portion of the oxide will combine with the earthy matter, and fuse into a glass, after part of the oxygen has been expelled. The crucible has another luted over it. The carbonate of manganese may be employed. When the oxide is mixed with flour and oil, and the crucible heated in the blast furnace, larger portions of manganese are easily reduced.

1252. Manganese is a brittle metal, with a colour like that of cast-iron. It may easily be pulverised in a mortar. At ordinary temperatures it gradually absorbs oxygen from air or in water, hydrogen being evolved in the latter case. At a red-heat it is quickly oxidated in air or water.

1253. OXIDE or PROTOXIDE OF MANGANESE (*Symb.* OMn, *or* ·Mn. *Eq. by W.* 35.7 = 0.8 + 27.7 Mn) may be obtained by passing a stream of hydrogen gas over any of the other oxides of manganese at a bright red-heat, placing them in a gun-barrel or porcelain tube made to traverse a furnace in the usual manner. One end of the tube must be connected with an apparatus from which a constant stream of hydrogen gas is disengaged, and the other with a tube dipping under water to carry off the superabundant hydrogen The excess of oxygen in the oxide unites with part of the hydrogen, and is converted into water, the oxide remaining in the tube in the form of a green powder. This oxide has been prepared also by heating to whiteness some of the other oxides with charcoal in a crucible. It may also be prepared by fusing together in a platinum crucible chloride of manganese mixed with two parts of carbonate of soda. Chloride of sodium is also formed, which may be removed by water.

1254. This is the basis of the principal salts of manganese. When heated to redness, it absorbs oxygen, and becomes the red oxide. It dissolves in sulphuric, nitric, and hydrochloric acids ; and is precipitated from the solution by potassa as a white hydrate. Exposed then to the air, it becomes red oxide.

1255. TERDINOXIDE (SESQUIOXIDE, or DEUTOXIDE) OF MANGANESE ($Symb.$ O^3Mn^2, or $:Mn^2$. $Eq.$ by $W.$ $79.4 = 0.24 + 55.4$ Mn). This compound may be obtained by exposing the binoxide to heat in an iron bottle.; oxygen gas is disengaged, and the terdinoxide remains of a dark brown colour. See page 11. It is regarded as a compound of one equivalent of the oxide and one of the binoxide of manganese. It occurs native,—pure, and as a hydrate.

1256. The RED OXIDE OF MANGANESE ($Symb.$ O^4Mn^3. $Eq.$ by $W.$ $115.1 = 0.32 + 83.1$ Mn) may be obtained by exposing the terdinoxide to a white heat, when an additional quantity of oxygen is disengaged. It may be considered as a compound of one equivalent of the binoxide with two of the oxide of manganese.

1257. Another oxide has lately been pointed out by Mr Phillips in a mineral which has been termed Varvicite, containing four eqs. of manganese and seven of oxygen.

1258. The BINOXIDE (BLACK OXIDE or PEROXIDE) OF MANGANESE ($Symb.$ O^2Mn, or $:Mn$. $Eq.$ by $W.$ $43.7 = 0.16 + 27.7$ Mn), occurs abundantly in the mineral kingdom, and is the compound from which all the other preparations of manganese are usually obtained. Its use in the preparation of oxygen and chlorine, and in several other processes, has been already described. It is contaminated with oxide of iron and earthy carbonates, silica, and alumina, in the state in which it is usually met with. It is procured in this country, in Devonshire and Aberdeenshire, and is also imported from Sweden.

1259. The binoxide of manganese is not altered by exposure to air or water. By heat it is deprived of part of its oxygen (25). It does not combine with acids ; but is resolved by them into oxygen, and the oxide. with which the acid combines. It has little action with nitric acid. It does not unite with alkalis.

1260. Binoxide of manganese is much employed in practical chemistry and in the arts. Heated to redness or boiled with sulphuric acid, it yields oxygen gas. With hydrochloric acid it

yields chlorine. It is used to give a dark coating to earthenware. In the glass manufacture, it is employed in small quantity to correct the tint caused by iron. It is used in calicoprinting to furnish sulphate of manganese, from which a bronze or dark brown colour is procured.

1261. MANGANESEOUS ACID (Symb. O³Mn or $\ddot{?}$Mn. *Eq. by W.* 51.7 = 0.24 + 27.7 Mn), which contains still more oxygen than the binoxide of manganese, may be obtained easily in combination with potassa, by mixing one part of the binoxide of manganese intimately with three or four of nitre, and exposing the mixture to a bright red-heat for half an hour in a crucible. The mixture should not fill more than a third of the crucible. In this process, the nitric acid of the nitre is completely decomposed, part of its oxygen combines with the binoxide of manganese and converts it into manganeseous acid, which remains in combination with the potassa; and the rest is disengaged along with the nitrogen. The manganesite of potassa prepared in this manner has a very green colour, and must be kept in close vessels. as it usually contains an 'excess of alkali, which renders it very deliquescent. It is usually called the *Mineral Chameleon*, from the different colours which its solution presents, when diluted with different quantities of water, or exposed freely to the air for some time.

1262. Reduce ten or twelve grains of the mineral chameleon to powder, put it into a deep glass vessel, and pour in a little water; it will immediately become of a very deep green colour, dissolving the manganesite of potassa; and by pouring in an additional quantity of water, it will pass through various shades of green, blue, and purple, and at last become of a red colour. These changes arise from the manganeseous acid attracting oxygen from the water, and being converted into MANGANESIC ACID, which has a deep red colour when dissolved in water, and communicates the same tint to this liquid when combined with potassa. The presence of a small portion of this acid occasionally communicates a pink tint to salts of the oxide.

1263. The binoxide of manganese being usually mixed with oxide of iron and other impurities, most of which are dissolved along with the oxide of manganese when digested in sulphuric or hydrochloric acid, the following process, pointed out by Dr Faraday, will be found convenient when a pure solution of man-

ganese is required. Mix one part of hydrochlorate of ammonia (sal-ammoniac) in fine powder with twice its weight of the binoxide of manganese, and expose the mixture to a dull red-heat in a crucible for a quarter of an hour ; the ammonia is disengaged, the binoxide loses oxygen, and the chlorine of the hydrochloric acid combines with metallic manganese alone, having a much greater affinity for this metal at a red-heat than for iron. As a great excess of binoxide is used, no chloride of iron is formed, and a pure solution of chloride of manganese is obtained, on digesting the remaining mass in water, and separating the iron and excess of manganese by filtration.

1264. Drop a little of the solution of ferrocyanate of potassa into the solution of chloride of manganese prepared in this manner ; a white precipitate is thrown down immediately—the ferrocyanate of manganese. Add a little of the same solution to a diluted solution of the chloride or sulphate of manganese, prepared by digesting the binoxide as it is usually procured in hydrochloric or sulphuric acids ; a precipitate immediately appears, but it has a rich blue colour, from the large quantity of ferrocyanate of iron that is thrown down with the ferrocyanate of manganese.

1265. Dr Thomson recommends manganese to be purified by operating with the solution prepared on digesting the binoxide in hydrochloric acid to procure chlorine. He states, " It" the solution, " is always contaminated with a good deal of iron ; and sometimes it contains copper and likewise baryta. Copper is easily thrown down by passing a current of sulphureted hydrogen gas through the solution. I then render it as neutral as possible by evaporation, and after diluting it with water, I add ammonia in small quantities at a time, as long as the precipitate appears red. I then filter. The liquid which passes through is colourless like water. It is proper to try whether the whole iron has been thrown down, by putting a few drops of it into a watch-glass, and adding a drop of the solution of prussiate of potash. If the precipitate be quite without any shade of blue, we may be sure that no iron is present. If the black oxide was free from baryta, nothing more is necessary to have the manganese quite pure. But if baryta be present, we must add a solution of sulphate of ammonia as long as a precipitate continues to fall. The liquid being now filtered, and mixed with a suffi-

cient quantity of bicarbonate of potash, pure carbonate of man ganese falls to the bottom, which requires only to be washed and dried."

1266. From the pure carbonate thus procured, the metal may be extracted in the same way as from the oxide (par. 1251), or solutions may be procured by dissolving it in the stronger acids.

1267. A pure carbonate of manganese may also be procured by the following process, pointed out by Forchammer. Mix equal parts of the binoxide and sulphuric acid, and heat them as long as any vapour of sulphuric acid comes away. Sulphates of manganese, iron, copper, &c. are thus formed. By lixiviation and filtering, the insoluble sulphates of baryta and lead are separated. The solution has then hydrosulphate of ammonia added as long as there is any dark precipitate thrown down. The iron and copper are thus separated. The liquid is then filtered, heated, and treated with bicarbonate of potash as above.

1268. Salts of manganese in solution are known by the following characters:

1. Ferrocyanate of potassa gives a white precipitate.

2. Hydrosulphates give a precipitate of a yellowish colour, a hydrated sulphuret of manganese; but hydrosulphuric acid does not occasion any precipitate when the oxide is combined with a strong acid.

3. The alkalis throw down a white precipitate, a hydrated oxide, which acquires a dark colour, gradually attracting oxygen on exposure to the air, and at length becoming red oxide of manganese.

4. If a portion of the precipitate thrown down by an alkali be heated before the blowpipe with borax in the oxidating flame, a glass is procured having a purple colour, more or less deep, according to the quantity employed. In the reducing flame, the colour disappears.

1269. A solution of the CHLORIDE of MANGANESE, for estimating the strength of a solution of the chloride of lime, may be obtained by evaporating to dryness the solution that remains after the preparation of chlorine by common hydrochloric acid and binoxide of manganese, digesting it afterwards in water and filtering the liquid produced in this manner. The chloride is also employed in calico-printing.

CHAP. IX.—CHROMIUM.

Symb. Cr. *Eq. by W.* 28.19. *Sp. gr.* 5.9. *Fused only by a very intense heat.*

1270. It is not easy to procure chromium in the metallic form, as it has a considerable affinity for oxygen. Small quantities have been obtained from a mixture of the oxide with charcoal, exposing it to heat in the manner directed for the preparation of metallic manganese (1251). The following are Vauquelin's directions for preparing this metal : Digest chromate of lead in fine powder with five times its weight of hydrochloric acid, evaporate the liquid to dryness, and digest the residuum in alcohol, by which a solution of the chloride of chromium is procured free from chloride of lead. Apply a gentle heat to this liquid till it assumes the consistence of a syrup, and then make it into a paste with oil and charcoal. It must then be put into a small crucible, and enclosed in a larger one filled with pounded charcoal ; and on heating it strongly in a forge for about a hour, chromium is procured. Chromic acid, he has stated, affords it more readily than the oxide, but he preferred the process with the chloride.

The ores from which chromium is procured are *dichromate of lead*, a red mineral, not very abundant, and *chromate of iron*, which is found in Shetland and other parts of Europe.

1271. Chromium has a white colour and exhibits the metallic lustre. It is a brittle metal, easily pulverized. It is very slowly acted upon by exposure to air and moisture. The acids, even aqua-regia, scarcely affect it,—but it is dissolved by the hydrofluoric acid. It is oxidated by fusing it with the carbonates or nitrates of the fixed alkalis.

1272. TERDINOXIDE (Sesquioxide, Protoxide, or Oxide) OF CHROMIUM. *Symb.* O^3Cr^2 or $:Cr^2$; *Eq. by W.* 80.38 $=$ O.24 $+$ 56.38 Cr. This compound is easily prepared by exposing the chromate of mercury to a strong red-heat for half an hour in an earthen crucible. The oxide of mercury is decomposed and volatilized, and the chromic acid parting with part of its oxygen, sesquioxide of chromium remains. There are other processes for

preparing the sesquioxide of chromium, but the above is the most convenient. By calcining in a close crucible equal weights of chromate of potassa and sulphur, the sesquioxide is procured, along with sulphate of potassa and sulphuret of potassium, which may be removed by water. When the bichromate of potassa is exposed to a full red-heat, this oxide is formed, and remains mixed with chromate of potassa, which may be removed by water.

1273. Sesquioxide of chromium, thus procured, is a green powder, insoluble in water and in acids, but capable of oxidation by fusion with nitrate or chlorate of potassa, when it becomes chromic acid, which unites with the alkali. It may be precipitated as a hydrate by digesting a solution of chromate of potassa with oxalic acid, or boiling a solution of the same salt with a mixture of equal parts of alcohol and hydrochloric acid, added from time to time until the solution becomes green ; and then adding ammonia in excess. When precipitated in this manner, it contains a considerable quantity of water, and is soluble in the acids. The water is expelled by heat, and the dry oxide remains as a fine green powder. When heated to redness, it assumes a glowing appearance like tinder, and is then rendered insoluble in acids. It communicates a fine green to glassy compounds when fused with them, and is much employed in the arts for this purpose.

1274. It is stated that it may be obtained in a state sufficiently pure for use in the arts, by calcining chromate of iron (chrome iron-ore) with nitre, lixiviating the mass, and boiling with sulphur the solution thus procured.

1275. The compound termed brown oxide of chromium, prepared by passing sulphurous acid gas through a solution of chromate or bichromate of potassa, is regarded as a compound of green oxide and chromic acid.

1276. CARBONATE OF CHROMIUM. This compound is procured by boiling a solution of bichromate of potassa with sugar, and then boiling the brown matter that is precipitated with a solution of carbonate of potassa.

1277. CHROMIC ACID. (*Symb.* O^{3}Cr ; *Eq. by W.* 52.19 = 0.24 + 28.19 Cr.) To prepare chromic acid in a pure state, Mr Unverdorben has proposed the following process. Mix 3 parts of fluorspar with 4 of the chromate of lead, and 5 of the strongest sulphuric acid ; the fluor-spar ought to be heated previously, and

reduced to a fine powder. Put this mixture into a leaden or platinum retort, apply a gentle heat, and condense in water the coloured gas that is evolved in this manner ; the gas appears in the form of red or yellow coloured vapours as it mixes freely with the air. Chromic and hydrofluoric acids are thus obtained in combination with water, and, on evaporating the liquid in a platinum vessel, the hydrofluoric acid is expelled, and the chromic acid is left.

In this process, part of the sulphuric acid unites with the oxide of lead of the chromate, and disengages chromic acid, while another portion, by acting on the fluor-spar, gives sulphate of lime and hydrofluoric acid (see Hydrofluoric Acid). The chromic and hydrofluoric acids produce the coloured gas.

1278. Dry chromic acid is of a deep red colour ; it is deliquescent, and its solution in water affords red crystals when carefully concentrated. Chromic acid parts with a portion of oxygen when exposed to a red-heat, and even when its solution in water is boiled or left in contact for some time with acids and many substances that have an affinity for oxygen, as alcohol and other liquids containing a considerable quantity of inflammable matter, the carbonaceous matter or hydrogen uniting with the excess of oxygen in the chromic acid, and the green oxide being retained in solution by the other acid that is mixed with it. It destroys the colour of indigo and some other vegetable colouring matters. Mixed with hydrochloric acid, a solution is obtained which can dissolve gold.

1279. CHLOROCHROMIC ACID was discovered by Dr Thomson, and may be prepared in the following manner. Mix 95 grains of dry bichromate of potassa and 112 of common salt ; put the mixture into a tubulated glass-retort capable of containing 3 or 4 ounces, and add 250 grains of sulphuric acid ; then adjust a flask or other receiver to the retort, and apply a gentle heat by a lamp or chauffer, continuing it while red fumes are disengaged. These cease to come over rather suddenly, and at the same time the materials in the retort present a green appearance. About 100 grains of red liquid are condensed in the receiver. The heat must not be applied after the red vapours are no longer formed.

1280. In this process, the bichromate of potassa and a portion of the chromic acid are decomposed along with the common salt.

Sulphates of potassa, soda, and chrome, remain in the retort, water and terchloride of chromium being produced by the reaction of the liberated chromic and the hydrochloric acid. The precise composition of the red liquid is still under discussion. Mr Giraud has formed a similar TERIODIDE OF CHROMIUM.

1281. Pour a few drops very cautiously on a little liquid ammonia (3 or 4 drops). Heat and light are immediately evolved, and the green oxide of chromium at the same time appears, mixed with vapours of the hydrochlorate of ammonia. If ammoniacal gas be brought in contact with a small quantity of the red liquid, spread over the surface of a wine-glass, the reaction is seen more conveniently, and there is no danger of any of the liquid being thrown about the operator. The ammoniacal gas for this purpose may be disengaged by heating a small portion of water of ammonia in a retort by a spirit-lamp, introducing the beak of the retort into the wine-glass from time to time ; the glass is broken when the gas is applied too long at a time to the red liquid.

1282. Alcohol and ether produce a similar effect when mixed in small quantity with chlorochromic acid ; the chlorine appears in all these cases to combine with hydrogen, when it is converted into hydrochloric acid. It acts violently on a number of other substances containing hydrogen in a condensed state. It inflames sulphur when poured upon it.

1283. FLUOCHROMIC ACID GAS is not so easily prepared, from the facility with which it is decomposed by glass vessels, the hydrofluoric acid uniting with the silica, while chromic acid is set at liberty ; it is prepared, by heating a mixture of fluor-spar, chromate of lead, and sulphuric acid, in the proportions already described (1277). A leaden retort should be used, similar to what has been recommended for the preparation of hydrofluoric acid.

SALTS OF CHROME.

1284. The salts of chrome are divided into two classes, viz. those in which the oxide acts the part of a salifiable base, and those where some other salifiable base is combined with chromic acid ; the latter are the most important.

1285 CHROMATE OF POTASSA is prepared from a mixture of

nitre and the common chrome iron-ore, usually termed chromate of iron, but which is composed of the oxides of chrome and iron mixed with earthy matter. The ore must be reduced to a very fine powder, and mixed with an equal weight of nitre, exposing the mixture to a red-heat in a crucible for about half an hour, when a small quantity of materials, as one or two ounces, is used. The nitric acid is• completely decomposed, converting the oxide of chrome into chromic acid, and the oxide of iron into peroxide. The chromic acid unites•with the potassa, form-ing chromate of potassa, and on boiling what remains in the crucible in water and filtering through paper, a clear solution of the chromate of potassa is procured, and the iron and earthy matter remain on the filter. The free potassa which the solu-tion always contains must then be neutralized by nitric acid, concentrating it afterwards by evaporation, that the nitrate of potassa may crystallize, after which, the remaining liquid will deposit crystals of the chromate of potassa when allowed to evaporate spontaneously. They have a lemon-yellow colour, and are soluble in twice their weight of cold water, and a much smaller quantity of boiling water. By exposure to an intense heat, this substance becomes green, fusing, and losing a por-tion of oxygen. A very small portion colours a very large quantity of water.

1286. The BICHROMATE OF POTASSA is prepared by adding sulphuric or nitric acid to a solution of the neutral chromate, sulphate of potassa being formed, while the chromic acid set at liberty unites with another portion of the chromate of potassa which is not decomposed. The solution at the same time as-sumes a deep red colour, and red crystals of the bichromate are procured by spontaneous evaporation. They are less soluble than the crystals of the neutral chromate of potassa, requiring about ten parts of cold water for their solution.

1287. Add a solution of the carbonate of potassa to a solu-tion of the bichromate of potassa till the excess of acid is neu-tralized ; the liquid will become of a yellow colour, chromate of potassa being formed. Then drop in sulphuric acid, that it may combine with the potassa which has been added, when the bichromate of potassa will be formed, the red colour returning again.

1288. The bichromate loses a portion of oxygen when ex-

posed to a strong red-heat, oxide of chrome and chromate of potassa being left.

1289. CHROMATE OF BARYTA is precipitated when a solution of chromate of potassa is added to a solution of hydrochlorate of baryta, hydrochlorate of potassa remaining in solution.

1290. CHROMATE OF LEAD is prepared by adding a solution of the chromate or bichromate of potassa to a solution of the nitrate or acetate of lead, as long as any precipitation takes place. It has a fine yellow colour, and is the pigment well known by the name of Chrome Yellow. It is soluble in nitric acid. It occurs native.

1291. DICHROMATE OF LEAD, called also subchromate, is composed of two equivalents of oxide of lead and one of chromic acid. It is formed when the chromate is boiled with about two-thirds of its weight of oxide of lead. It may be procured also by mixing intimately one equivalent of chromate of lead and one of carbonate of lead ; the carbonic acid of the latter is disengaged, and the oxide combines with the chromate. The ebullition may be carried on in a glass or earthen vessel for an hour or two. The process first proposed by Mr Badams consists in boiling one equivalent of chromate of potassa with two of carbonate of lead. By digesting the chromate in an alkali, part of the acid is withdrawn, and the oxide of lead remains in union with a portion of chromate, forming the dichromate. It is in this manner that the dichromate is formed in dyeing, lime-water being frequently employed. The dichromate has a fine orange colour. By adding an acid to the dichromate, it is turned yellow, being then rendered chromate.

1292. CHROMATE OF MERCURY, which has an orange-red colour, is easily prepared by adding a solution of the chromate of potassa to a solution of the nitrate of the oxide of mercury as long as any precipitation takes place ; nitrate of potassa remains in solution.

CHAP. X.—COBALT.

Symb. Co. *Eq. by W.* 29.5. *Sp. gr.* 7.83 *or* 8.5 *It fuses at a temperature a little below the melting point of iron.*

1293. Cobalt is usually found in union with arsenic. The ore termed *glance cobalt*, the most abundant of its ores, contains chiefly cobalt, arsenic, and sulphur. It is also found as an oxide, and in union with iron and arsenic. Its ores frequently contain also a quantity of copper. It is generally present in small quantities in meteoric iron.

1294. Cobalt may be prepared from *zaffre*, an impure oxide of this metal, the residue of one of the principal ores of cobalt (arseniuret), after exposing it to heat to drive off the sulphur and arsenic which are usually combined with it. To procure cobalt from this substance, it must be mixed with thrice its weight of black flux, and exposed to a strong heat in a crucible. It is never pure, however, when prepared in this manner, being contaminated in general with arsenic, copper, and iron, and frequently with nickel.

1295. To obtain pure cobalt, the following process may be resorted to. Dissolve zaffre (impure oxide of cobalt), in hydrochloric acid, diluted with a little water, and transmit a stream of hydrosulphuric acid through the solution, that any arsenic which it contains may be precipitated in the form of sulphuret; sulphuret of copper is also precipitated. Introduce a plate of iron, which will gradually precipitate any remaining copper, and then boil the solution with nitric acid, and add an excess of carbonate of potassa in solution; the iron and the cobalt are both precipitated, and to remove the former, it has been recommended to digest the mixture in a solution of oxalic acid. The insoluble oxalate of cobalt which is left may then be decomposed by exposing it to a red-heat in a covered vessel, without any addition, when metallic cobalt is procured, and appears in the form of a dark powder. To fuse it an intense heat must be applied.

1296. Cobalt is little acted on by air, except at a high temperature, when it is oxidated. It decomposes water at a red-

heat, hydrogen being evolved. It is readily dissolved by nitric acid, but sulphuric and hydrochloric acids have little action with it. It has a greyish colour with a tinge of red, and is brittle.

1297. OXIDE OF COBALT (*Symb.* OCo, *or* ·Co. *Eq. by W.* 37.5 $= 0.8 + 29.5$ Co.) This compound may be procured by adding potassa to a solution of the nitrate of cobalt. The oxide is precipitated as a blue hydrate. This absorbs oxygen when exposed to the air, and assumes a greenish colour. Dr Thomson recommends the hydrate to be kept for half an hour at a cherry-red heat, by which any water and absorbed oxygen are expelled, and the oxide remains of a fine blue colour. The oxide may also be procured by exposing carbonate of cobalt to a red-heat in a vessel excluded from access of air. It is the basis of the salts of cobalt. It dissolves readily in the acids, and also in ammonia. When heated not too much or too long in air, it passes to a brown and then to a black colour, acquiring a large additional quantity of oxygen. Oxide of cobalt is particularly distinguished by the fine blue tint which it imparts to vitreous compounds when heated along with them.

1298. Metallic cobalt is not employed in the arts : the impure oxide fused with silica and potassa gives a fine blue-coloured glass, *zaffre*, which is then ground to powder, and receives the name of *smalt*, much employed to give a blue colour to glass, and the glazing of earthenware.

1299. Solutions of salts of cobalt give a blue-coloured precipitate with solutions of the alkalis. and on heating it with borax before the flame of the blowpipe, placing it upon a piece of brick or other earthenware, a blue-coloured glass is procured.

1300. Ferrocyanate of potassa gives a light green-coloured precipitate, and alkaline hydrosulphates give a dark coloured precipitate. Hydrosulphuric acid does not precipitate cobalt.

1301. NITRATE OF COBALT may be prepared by digesting cobalt in nitric acid diluted with water ; the solution affords brownish-red crystals on concentration.

1302. SULPHATE OF COBALT is prepared easily by digesting carbonate of cobalt in diluted sulphuric acid.

1303. CARBONATE OF COBALT is precipitated when nitrate of cobalt and carbonate of soda are mixed together in solution. It is of a pink hue.

1304. The solution of the CHLORIDE OF COBALT is used as a

sympathetic ink ; characters traced with it on paper leave no mark when dry, if the solution be not very strong ; and appear of a blue colour when it is exposed to a gentle heat, so as to expel the water, which fades again as it cools, or if it be put into water. The solution is obtained easily by dissolving the carbonate in hydrochloric acid, or by digesting cobalt in one part of hydrochloric acid mixed with half its bulk of nitric acid, and two or three parts of water, evaporating the liquid obtained in this manner to dryness, and then dissolving the residue in water. The solution has a pink colour. Red crystals may be procured by evaporation.

1305. If copper or iron be present in the solution, the traces appear green instead of blue.

1306. A solution for sympathetic ink may be procured by digesting one part of cobalt (or zaffre) with four parts of nitric acid, and adding to the solution one part of common salt diluted with four of water. Salt produces a green as well as copper ; with cobalt alone, the tint is blue.

CHAP. XI.—ARSENIC.

Symb. As. *Eq. by W.* 37.7. *Sp. gr.* 5.7. *It is volatilized at* 360°.

1307. Metallic Arsenic occurs native, but it is rare. It may be prepared by exposing arsenious acid, or the white oxide of arsenic, as it is sometimes termed, to heat along with charcoal in fine powder ; the oxygen of the acid unites with the carbon, and forms carbonic acid, which escapes in the gaseous form, while the metal is at the same time volatilized, and must be condensed in a close vessel, so that it may not be exposed to the action of the air. The best method of conducting the process, when a small quantity is required, is to mix the arsenious acid intimately with about twice its weight of charcoal (or black flux), taking care to have them both perfectly dry, and expose the mixture to heat in a crucible, luting another over it in an inverted position to collect the product, and leaving a small aperture for the escape of gas. The lower crucible should be placed in a sand-bath furnace, and the upper one kept as cool as pos-

sible, and completely out of the sand, that the arsenic may condense ; the process may be easily conducted with a small chauffer or furnace, taking care always to protect the upper crucible from the heat as much as possible. Dr Christison prefers charcoal to the black flux (which is generally recommended), more especially when only a small quantity of materials is operated on, for, with charcoal, the whole of the metallic arsenic is obtained from the arsenious acid, while, if the black flux be used, which is composed of carbonate of potassa and charcoal, part of the arsenic is retained. The charcoal should be ignited in a crucible before it is used, that all adhering moisture may be removed. The arsenious acid and charcoal should be mixed before they are introduced, and a small portion of charcoal should be thrown over the mixture before heating it. Occasionally, also, when small portions are used, the charcoal above the mixture may be heated first, and the arsenic sublimed through it ; in this manner, any minute quantity of arsenious acid that may escape decomposition at first, is decomposed as it passes through the hot charcoal.

1308. Instead of using a crucible, the reduction may be effected more easily, in operating with small quantities, by heating the mixture in a glass-tube, held in the flame of a spirit-lamp ; and in all test experiments a glass-tube is invariably preferred, as the operation can be conducted with little or no loss, and much more conveniently, while, with a crucible, there is always considerable loss, the product is not so easily collected or examined, and when the quantity is very small, the crucible is totally unfit for the operation. The tube must be perfectly dry, and the mixture should be placed in a small piece of paper, so as to slide readily down the tube when held in an inclined position. The student should repeat this process frequently, in tubes of different sizes, from half an inch to a quarter of an inch in diameter, and from two to four inches long, using different quantities of the mixture; from one-eighth of a grain to seven or eight grains, till he has become quite familiar with the appearance which the metallic arsenic presents.

1309. Berzelius has recommended a tube of the form represented in figure 203, to be used, when a very minute quantity is operated on ; the materials may then be introduced by a small funnel made on purpose, which descends within the ball, pushing them down with a small wire. In this manner the sides of

the tube are kept clean, and on heating the mixture, the Fig. 203. metallic arsenic sublimed condenses within the narrow part of the tube, and a distinct crust of metal is thus procured in many cases, where, had it been diffused over a larger surface, it might have been scarcely perceptible. The bulb at the extremity of the tube should not be filled more than one-half or three-fourths full. When the crust is to be removed from the tube, a file should be drawn across it immediately· below the part where the metallic arsenic has collected; a slight pressure will then be sufficient to break off the lower part of the tube, and the metallic arsenic may be separated by a penknife.

1310. Metallic arsenic is a very brittle metal, and may be easily reduced to powder in a mortar. It is of a steel-grey colour, called bluish-white by some, and has a considerable lustre. It presents the appearance of highly polished steel when it has been condensed upon a smooth surface, as a piece of glass; this is seen, however, only where it has adhered to the glass, and the other side presents the appearance of a congeries of small crystals, somewhat similar in its general appearance to many of the ornaments of cast-steel that are now made, when their surface is intersected by many lines. After sublimation in a glass-tube, metallic arsenic may be recognised by its appearance, even when the quantity does not exceed the 280th part of a grain. (Christison.)

1311. Arsenic tarnishes on exposure to air, moisture, or acid vapours, becoming dark, and acquiring a film of oxide, or mixture of metal and oxide. Some specimens are very slowly oxidated, while others soon crumble down to a powder (an imperfect oxide). It is little acted on by cold water, but is said to be oxidated and dissolved when boiled with water.

1312. Put a grain or two of metallic arsenic on a plate of iron, and expose it to heat; the arsenic is speedily volatilized, and produces a strong odour, similar to that of garlic. It sublimes at 360°, condensing unchanged if excluded from access to oxygen, but oxidated if air or oxygen be present. Expose another portion of metallic arsenic to heat in a glass-tube, and sublime it repeatedly from one part to another; it attracts oxygen from the air, and is converted into arsenious acid, the

crystals being very brilliant, and presenting an adamantine lustre. At a high temperature, it burns with a blue flame.

1313. ARSENIOUS ACID (called also *White Arsenic*, *White Oxide of Arsenic*, or, commonly, *Arsenic*). *Symb.* O³As², or ⫶As² ; *Eq. by W.* 99.4 = 0.24 + 75.4 As. This is the most important compound of arsenic. It occurs native, but is usually procured by roasting the *arseniuret of cobalt* in a reverberatory furnace, when the arsenic is sublimed and oxidated, and condenses in cakes in the chimney of the furnace. It is sublimed a second time in iron vessels, and then forms the common *arsenic*, or *white arsenic* of commerce, which, reduced to powder, gives the *white arsenic* of the shops. It is the product formed when arsenic burns, or is sublimed in contact with air.

1314. When newly sublimed, it is in brittle cakes, semi-transparent, of a glassy appearance, and adamantine lustre. On being kept it becomes white and opaque, without appearing to be altered in its chemical constitution. Its specific gravity is 3.72. It is sublimed at 380°, and condenses in octohedrons. It gives out no odour when sublimed if perfectly free from metallic arsenic. When heated very suddenly to a temperature above 380°, it melts and runs into a glass, which soon, however, becomes opaque as before.

1315. Arsenious acid has little or no taste, as Dr Christison first distinctly pointed out, though it was previously said to have an acrid taste, leaving a slight impression of sweetness. The acrid taste is now considered to have arisen from the inflammation which it subsequently excites, having been mistaken for the taste. It seems to be generally considered that it is slightly sweet.

1316. Arsenious acid possesses the characters of an acid, reddening litmus paper, and combining with the alkalis. Its compounds with the various bases are called *arsenites*. They may generally be formed by boiling the arsenious acid with the respective bases and water.

1317. Arsenite of potassa is the active ingredient in *Fowler's arsenical solution*, and in the *liquor arsenicalis*. It may be formed by boiling arsenious acid in water with an equal weight of carbonate of potassa.

1318. Different statements have been made by authors as to

the solubility of arsenious acid in water. The opaque and transparent varieties differ in their degree of solubility, the opaque arsenious acid being the more soluble of the two. The presence of various organic matters, as albumen or mucus, renders it less soluble in water (Christison).

1319. According to Klaproth, who examined particularly the solubility of arsenious acid, 1000 parts of water at 60° dissolve only 2.5 parts (1–400th) of arsenious acid, while 1000 parts of boiling water can dissolve 77.75 parts (1–13th), but the solution, when cooled, retains 30 parts (1–33d). Guibourt found that 1000 parts of cold water take up 9.6 of the transparent, and 12.5 of the opaque arsenious acid. According to Fischer, 12.3 parts of boiling water dissolve 1 of arsenious acid, while the same quantity of the acid requires 66.5 parts of cold water to dissolve it. It may be said that 13 parts of boiling water take up 1 of arsenious acid, of which about 3–8ths are retained when the liquid cools, water thus dissolving about 1–34th of arsenious acid when first heated with it. According to Guibourt, 18 of the transparent variety, and 29 (1–34th) of the opaque, remain in solution in 1000 parts of water in which they have been placed while hot. Accordingly, to procure a strong solution of arsenious acid, boil the opaque variety about twenty minutes in 34 parts of water.

1320. The arsenious acid deposited from a hot watery solution as it cools, or by slow evaporation, appears in octohedral crystals. The solution tastes slightly sweet, and reddens litmus.

1321. Arsenious acid is soluble in about 80 parts of alcohol at 60°. It is also dissolved by several of the acids.

1322. This substance is an extremely virulent poison, whether taken internally, or applied externally to any exposed surface, as a wound or open sore. Internally, it causes inflammation and gangrene of the stomach and intestines.

1323. The solution of hydrosulphuric acid has been recommended as the best antidote to arsenious acid, the yellow sulphuret of arsenic that is formed being comparatively inert; it is not free from danger, however, and has sometimes produced death, though it is certainly much less virulent in its action than arsenious acid. Lime water is also recommended, to prevent the solution of the poison, but the great object in all cases must be to excite vomiting as speedily as possible; and to give large quantities of mucilaginous liquids to involve and suspend

the poison till it has been rejected.   The hydrated peroxide of
iron, precipitated from a persalt of iron by ammonia, has been
recommended as an antidote.

1324. As Arsenious Acid is frequently administered as a
poison, the student should perform a number of experiments,
to render himself familiar with the appearances which the dif-
ferent re-agents that have been recommended for detecting it
present with arsenious acid when pure, or mixed with a number
of other substances, such as are usually found in the contents of
the stomach, or are likely to have been given at the same time,
either as an antidote, or for any other purpose.   It has occa-
sionally occurred in the common salt of commerce in a small
proportion, giving rise to serious illness.

1325. Mix 1 part by weight of arsenious acid and 2 of car-
bonate of potassa, and boil the mixture in ten or twelve times
its weight of water ; the arsenious acid unites with the potassa,
and is very speedily dissolved, the arsenite of potassa being
much more soluble than pure arsenious acid.   This solution
may be used for experiments.   As the excess of alkali which
the solution contains (when the materials have been mixed in
the above proportion), must react upon many of the tests used
for the detection of arsenic acid, the student must always
bear in mind the precise composition of the fluid on which he
is operating.

1326. There are five methods of detecting arsenious acid in
solution,—1. Testing the liquid with *hydrosulphuric acid;* 2. With
a *solution of copper* ; 3. With *ammoniaco-nitrate of silver* ; 4. *Ex-
tracting the metal* from the precipitated sesquisulphuret by *heat
and the black flux ;* dissolving it and applying the previous tests
if necessary ; 5. *Forming and burning arsenureted hydrogen.*

1327. (1.) Hydrosulphuric Acid as a test for arsenious acid. *
Mix a few drops of the saturated solution of arsenious acid with
seven or eight ounces of water, and pass a stream of hydrosul-
phuric acid gas through the liquid.   The sulphur of the gas
combines with the metallic arsenic, rendering the liquid of a
yellow colour, but very faint, from the small quantity of mate-
rials present, and the hydrogen combines with the oxygen of
the arsenious acid, forming water.   Boil the liquid to expel the
excess of hydrosulphuric acid, and then set it aside for several
hours, when a minute quantity of sesquisulphuret of arsenic will

be gradually deposited at the bottom. The hydrosulphuric acid may be prepared in a bottle with a bent tube fitted to it by a cork, the other extremity being introduced into a glass containing the solution.

1328. Pass a stream of hydrosulphuric acid gas through a strong solution of arsenious acid in water ; observe the large quantity of the sesquisulphuret of arsenic which is precipitated of a rich yellow colour ; place it on a filter when no farther precipitation takes place, and after washing it several times with water, set it aside that it may dry.

1329. Transmit a stream of hydrosulphuric acid gas through a solution of the arsenite of potassa, taking care to have a slight excess of alkali. No precipitate is thrown down, nor does the gas appear to have any effect upon the liquid : hydrosulphuric acid gas not being capable of decomposing arsenious acid when in combination with potassa. Add an excess of hydrochloric acid or acetic acid, and immediately the characteristic yellow-coloured precipitate will appear. The sesquisulphuret of arsenic is soluble in potassa or ammonia.

1330. The hydrosulphuric acid alone cannot be regarded as an infallible test of the presence of arsenic, as some other metals, particularly tin and antimony, might give indications bearing a considerable resemblance to those of arsenic. The farther method of proceeding will be described immediately.

1331. (2.) SOLUTION OF COPPER as a test of arsenious acid. Put a few drops of the solution of arsenious acid in water into an ounce or two of water, and add a small quantity of a solution of the sulphate, nitrate, or acetate of copper. The liquid remains quite transparent and colourless, the arsenious acid not having so great an affinity for the oxide of copper as the acid with which it is already combined. If a small quantity of an alkaline solution (potassa or its carbonate) be now added, the alkali will unite with the acid of the salt employed, and remain in solution, and the arsenious acid combining with the oxide of copper will form arsenite of copper, which is insoluble in water, and is precipitated of a grass-green colour.

1332. If the arsenious acid shall have been previously combined with potassa, the grass-green precipitate appears immediately. Mix a drop or two of the solution of arsenite of potassa with a solution of the sulphate of copper in a glass of water :

the characteristic green-coloured compound is immediately form
ed.   The precipitate procured in this manner is *Scheele's green*,
used as a pigment.

1333. If the student should operate with a solution contain-
ing arsenite of potassa and an excess of potassa also, then, on
adding a small quantity of the cupreous salt, the potassa in ex-
cess alone acts upon it, uniting with its acid and precipitating
hydrated oxide of copper, of a blue colour, and very different
from the compound of arsenious acid and the oxide.   Nor is any
arsenite of copper thrown down till the oxide of potassa shall
have been neutralized in this manner.   It is obvious, therefore,
that should a great excess of potassa be combined with arsenious
acid in any liquid under examination, the large quantity of
oxide precipitated, before any of it is thrown down in combina-
tion with the arsenious acid, might completely prevent the green-
coloured precipitate from being seen.   The oxide of copper
precipitated may be dissolved by adding small quantities of
sulphuric acid till the green precipitate appears.   At the same
time, it must not be forgotten, that an excess of sulphuric acid
will dissolve the arsenite of copper.

1334. Add a solution of potassa to a solution of the sulphate
of copper, and compare the precipitate that appears with that
which is thrown down by the arsenite of potassa.

1335. Instead of using potassa to combine with the acid of
the salt of copper, and allowing the arsenious acid to unite with
the oxide, a solution of copper in ammonia is frequently em-
ployed, and indeed it is to be preferred, as it is easy to combine
the salt of copper with the exact quantity of ammonia that may
be required for the precipitation of the arsenious acid; the pre-
cipitate that is thrown down in this case, however, has not such
a rich green colour as when potassa is used.

1336. To prepare a solution of a salt of copper for this pur-
pose, ammonia must be added to it till the precipitate that is
thrown down at first is *almost* entirely redissolved, decanting
the deep blue-coloured liquid that is obtained in this manner,
and keeping it in a bottle accurately closed, otherwise the am-
monia will soon escape on exposure to the air.   The ammonia
unites with the acid of the salt, forming a salt which remains
in solution, and the precipitate that is thrown down consists of
oxide of copper, which is redissolved by the ammonia that is

afterwards added. If more ammonia be used than is sufficient to redissolve the whole of the precipitated oxide, the solution does not give any precipitate with arsenious acid, the arsenite of copper being soluble in an excess of ammonia.

1337. Add a few drops of a solution of the ammoniaco-nitrate of copper, prepared in the manner described, to a solution of arsenious acid. Arsenite of copper is immediately precipitated. Diffuse the precipitate through the liquid, and divide it into two portions ; then add a little nitric acid to one and some ammonia to the other ; the precipitate in each is redissolved, being soluble both in nitric acid and ammonia.

1338. The ammoniacal solution of copper cannot be considered a certain test of the presence or absence of arsenious acid in liquids containing infusions of organic matter, as in some such fluids a greenish precipitate is sometimes caused by it though no arsenious acid be present ; while in others, the arsenite of copper, though present, is sometimes held in solution.

1339. (3.) NITRATE OF SILVER, as a test of arsenious acid. Drop a solution of nitrate of silver into a solution of arsenious acid in distilled water. No precipitate is thrown down, nitric acid having a stronger affinity for oxide of silver than arsenious acid. If a little potassa be now added, it combines with the nitric acid and forms nitrate of potassa, which remains in solution ; and the arsenious acid, combining with the oxide, forms a yellow-coloured precipitate—the arsenite of silver.

1340. Add a solution of the nitrate of silver to a solution of phosphate of soda. Phosphate of silver is precipitated, of a yellow colour, and nitrate of soda remains in solution. The nitrate of silver cannot, therefore, be used as a test of the presence of arsenious acid in solutions which may be suspected to contain phosphate of soda, as in liquids obtained from the stomach of an individual supposed to be poisoned by arsenic. The precipitate of the phosphate is smooth and uniform, that of the arsenite, curdy.

1341. Prepare a solution of the ammoniaco-nitrate of silver, by adding ammonia in small quantities at a time to a solution of the nitrate of silver, proceeding in the same manner as in the preparation of ammoniaco-nitrate of copper. Then drop a little into a very diluted solution of arsenious acid ; the ammonia

remains in combination with the nitric acid, and the arsenious acid, combining with the oxide, gives the characteristic yellow-coloured precipitate of arsenite of silver.

1342. If the ammoniaco-nitrate be mixed with a solution of the phosphate of soda, a white precipitate will be thrown down, instead of the yellow-coloured precipitate which the nitrate of silver gives with a solution of this salt; and accordingly, the ammoniaco-nitrate of silver is always preferred to the nitrate in testing any liquid for the presence of this poison.

1343. Precipitate some arsenite of silver from a solution of arsenious acid by the ammoniaco-nitrate of silver, diffuse the precipitate through the liquid, divide it into two portions, and add ammonia to one and nitric acid to the other; both will be redissolved, and accordingly great care must be taken to have no excess either of acid or alkali in using the nitrate of silver as a test of the presence of arsenious acid, otherwise no precipitate will appear, even though a considerable quantity of arsenious acid should exist in solution.

1344. The test with silver is often very obscure when organic matters or common salt happen to be present in the solution. The colour of the precipitate is modified, or it does not appear at all. Alone, it cannot be regarded as a certain test of the presence of arsenic in a mixed liquid.

1345. Mix some lime-water with a small quantity of a solution of arsenious acid; arsenite of lime is immediately precipitated in the form of a white powder. Add arsenious acid in excess to the precipitated arsenite of lime; it is soon dissolved.

1346. Put a few drops of a solution of the bichromate of potassa into a solution of arsenious acid. The liquid assumes a rich pea-green colour after standing for some time; heat a little of it by a spirit-lamp, and the green colour is developed immediately. The change of colour is owing to the arsenious acid attracting oxygen from part of the chromic acid, and converting it into oxide of chrome.

1347. Drop a little of the solution of bichromate of potassa into a solution of tartar emetic; the liquid assumes the same green colour as in the preceding experiment, a circumstance that was pointed out by Mr Lawrence Reid, and accordingly

the bichromate of potassa cannot be used as a test of arsenic in any solution which may be suspected to contain tartar emetic. Many deoxidating agents produce a similar effect.

1348. The student, having now made himself familiar with the appearances which the most important tests for the detection of arsenious acid produce when mixed with a solution of this substance, and the precautions which he must take in applying them, should perform a number of experiments in the next place with liquids containing animal and vegetable matter, and mixed with arsenious acid both in solution and in the solid form, till he is able to detect it when the liquid upon which he is operating contains only a very minute portion of arsenious acid. He must recollect, however, that in operating with mixed liquids, such as are generally met with in cases of poisoning by arsenious acid, where a variety of animal and vegetable principles are intimately blended together, and where various kinds of saline matter are also likely to be present, he cannot expect that he will be able to recognise it so easily as in a solution of pure arsenious acid in water. It is now admitted, indeed, that we cannot depend upon the appearances which any of the tests present when mixed with these liquids, as unequivocal indications of the presence of arsenious acid, as it has been proved that they often fail in producing the characteristic precipitates in such compound fluids, though arsenious acid may be present, and occasionally they cause the same appearance as when arsenious acid is present, though the liquid does not contain any. Accordingly, though considerable information may be obtained by applying the tests we have described to mixed solutions suspected to contain the poison, and. when they all concur in the indications which they give of arsenious acid, little, if any, doubt can be entertained of its presence ; still, in order to avoid every source of fallacy, it will be necessary to continue our investigations farther, separating the matter that appears to have produced the characteristic precipitate with the arsenious acid, and extracting the metal itself, if any arsenious acid shall have been present.

1349. (4.) REDUCTION OF THE METAL BY THE BLACK FLUX TO DETECT ARSENIOUS ACID. For this purpose Dr Christison recommends hydrosulphuric acid to be employed, dispensing with

the other tests. The liquid should be boiled and filtered in the first place, and then acidulated with acetic acid, to coagulate any albuminous or other organic matters that might interfere with the subsidence of the precipitate, or by the viscidity they induce, with the filtration ; and also to prevent any alkaline matter present from interfering with the precipitation. Acetic acid is preferred to nitric or sulphuric acid, as it does not decompose the hydrosulphuric acid.

1350. Should the quantity of organic matter in the liquid be such as to interfere seriously with the filtration, it should be evaporated to dryness by a gentle heat, and a new solution made by boiling the dry mass with distilled water. The viscid or organic matters are thus rendered insoluble, and a solution is procured, free from them, and in a fitter state for the application of the hydrosulphuric acid. Care must be taken not to raise the heat too high in evaporating, which might dissipate the arsenious acid.

1351. A stream of hydrosulphuric acid gas is then to be passed through the liquid, continuing it at least for half an hour. The liquid is then to be boiled for a few minutes to expel any excess of hydrosulphuric acid. The precipitate is then to be collected on a filter, washed repeatedly with water, and dried by a temperature not exceeding 212°.

1352. On mixing it intimately with about twice its weight of black flux, and exposing it to heat in a glass-tube over a spirit-lamp, the potassium in the black flux combines with the sulphur, and the metallic arsenic is sublimed in the same manner as in the reduction of arsenious acid by the same substance. The size of the tube must be adapted to the quantity of the precipitate which has been procured ; the most convenient size is about three or four inches long and about a quarter of an inch in diameter ; the mixture should not fill more than half an inch of the lower part of the tube, and smaller tubes should be used when only a very minute quantity of matter has been precipitated.

1353. If a crust of metallic arsenic should be obtained, its steel-grey lustre, its brittleness, the facility with which it is volatilized, and the garlic odour that is at the same time produced, will be sufficient to distinguish it from any other substance ; if, however, there are only very indistinct appearances of the me-

tallic arsenic, the following is the method that I have in general found most convenient for ascertaining if arsenic be present. The tube is to be exposed again to heat over the spirit-lamp. till the matter that has been sublimed is carried a little farther up the tube, and completely separated from the black matter that remains at the bottom; the lower part of the tube must then be broken off, drawing a file across it previously that it may be easily removed, and the upper part put into another glass-tube and boiled for five or ten minutes with a little water to which a few drops of nitric acid have been added, taking care to have an excess of acid. If the tube be coated with any arsenious acid, it will be immediately dissolved, and converted into arsenic acid, and if any metallic arsenic should be present, it also will be converted into arsenic acid, attracting oxygen from the nitric acid and being dissolved at the same time, so that the liquid may now be considered as a solution of arsenic acid in water with a small quantity of nitric acid. Accordingly, on neutralizing the excess of acid by dropping ammonia into it through a test-tube drawn out at the extremity over a spirit-lamp (so as to represent a small funnel terminating in a capillary tube), and adding a little nitrate of silver, a characteristic *brick-red* precipitate, *arseniate of silver*, will appear. Arsenious acid is formed when there is an excess of metallic arsenic in proportion to the quantity of acid employed.

1354. Instead of operating in this manner, should a farther test be considered desirable, Dr Turner recommends the arsenic to be volatilized up and down in the tube, heating it by a spirit-lamp. The arsenic oxidates as it is exposed to the air in this manner, and small crystals of an adamantine lustre and presenting triangular facettes may be easily seen. It will probably, however, be satisfactory to many who may not have had much experience in operating with this substance to complete the examination, by proceeding in the manner described in the preceding paragraph; or, by dissolving the arsenious acid after it shall have been formed in the manner advised by Dr Turner, boiling it for this purpose in water, and testing it afterwards with the more important reagents. Mr Graham and Mr Clark have recommended a similar process; they boil the tube containing the sublimate in a little water with a drop of caustic ammonia,

neutralize the solution with a little nitric or acetic acid and then apply the ammoniaco-nitrate of silver, the ammoniaco-sulphate of copper, &c. in the usual manner.·

1355. The indications given by the different tests are free from every source of fallacy when they are added to solutions prepared in this manner, as the arsenious acid is thus removed from all the animal and vegetable matter that might have interfered with their action in the mixed liquid. Infusion of astringent matter and some other vegetable and animal substances, which are frequently met with in the liquid contents of the stomach, have been shewn by Dr Christison to be capable of retaining in solution the precipitates that arsenious acid gives with the ammoniaco-nitrates of copper and silver, or of causing similar discolorations. Tartaric and acetic acids appear to be solvents in some cases, arsenite of silver being soluble in both.

1356. Orfila has proposed to use chlorine, and Mr Phillips animal charcoal, to decolorize mixed fluids suspected to contain arsenious acid, and allow the usual tests to be applied in the liquid way, without previously removing the arsenious acid, and subjecting it to some process of reduction : but though both may occasionally be used with advantage, it will be better to adopt the method we have already mentioned. Chlorine, indeed, converts arsenious acid into arsenic acid. It appears also, from the experiments of Dr Christison and Dr Paris, that charcoal is capable of precipitating arsenious acid from its solution in water.

1357. (5.) Detection of arsenious acid by forming ARSENURETED HYDROGEN. Mr Marsh of Woolich has proposed a very ingenious mode of detecting arsenic in compound solutions, by converting it into arsenureted hydrogen. This is effected by acidulating the solutions with aqueous sulphuric acid, and adding fragments of zinc, proceeding in the same manner as in the preparation of hydrogen gas. When this gas is developed in any solutions containing arsenic, it combines with the metallic arsenic, and forms arsenureted hydrogen gas, which is thus separated at once with effervescence from all the materials that might have influenced the reaction of tests applied to the solution.

1358. On the small scale, a bent glass tube *a b* (Fig. 204) may be used, a piece of zinc (*a*) being suspended from the cork into which the stopcock is fixed, the stopcock being opened slowly when a sufficient quantity of gas has been accumulated, and a light applied, so as to inflame the arsenureted hydrogen as it escapes. The gas ought to be produced slowly when the quantity of materials is small, by using no more aqueous sulphuric acid than is necessary to produce effervescence.

"1359. When a larger quantity of materials is to be examined, an apparatus may be constructed of the form shewn in the annexed figure (205), and resembling Dobereiner's lamp. (See Hydrogen, par. 84.)

Fig. 204.
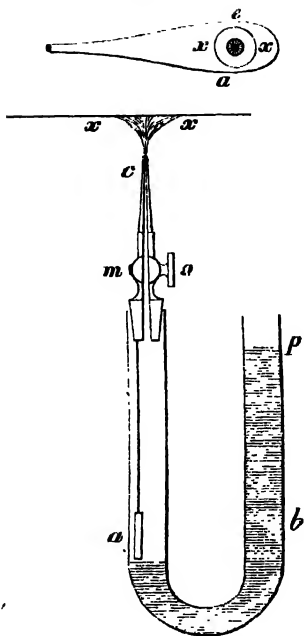
Fig. 205.
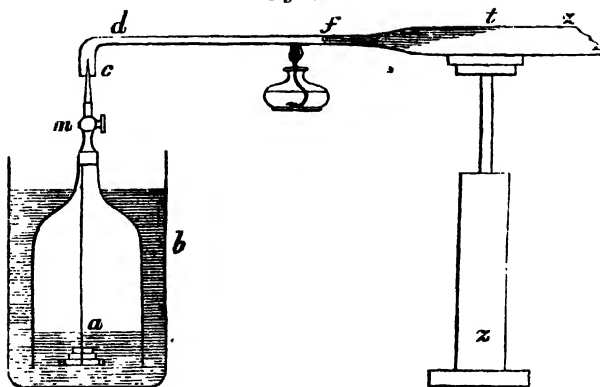
1360. In examining arsenureted hydrogen, it may be recognised by the flame with which it burns, but more particularly

by the deposition of metallic arsenic and arsenious acid when the flame is directed upon a piece of cold glass or porcelain. See $x\,x$, Fig. 204. The hydrogen produces water as it combines with the oxygen of the air, and the metallic arsenic with oxygen forms arsenious acid. But as the exterior film of gas is consumed, part in the interior is decomposed and precipitates metallic arsenic, precisely in the same manner as coal-gas deposits carbon. A great variety of appearances may be seen, and concentric rings of arsenic ôr arsenious acid according to the size of the plate applied, and the manner in which it' is brought in contact with the flame. This is represented in the upper part of Fig. 204.

1361. When the quantity of material is extremely minute, Professor Liebig recommends the arsenureted hydrogen to be transmitted through a small tube of glass (free from oxide of lead that it may not fuse easily) and heated, so that the arsenureted hydrogen may be completely decomposed. See $d\,f\,t$, Fig. 205. The metallic arsenic is then seen beautifully immediately beyond the part that is heated, and beyond it a little arsenious acid is generally observed ; the extremity of the tube should be closed, but not tightly, with a little cotton, so that any gas may escape, while the air shall be prevented from entering freely.

1362. As it has lately been pointed out, by Mr L. Thompson, that antimony may be removed from its solutions by hydrogen in the same manner as arsenic, care must be taken in all cases where there is a possibility of antimony being present to carry the investigation further. Thus, metallic arsenic is rapidly and easily volatilized by heat, but antimony requires a higher temperature and runs into globules. Again, the nitrate of silver, the sulphate of copper, or hydrosulphuric acid may be applied in the manner already described to the crust produced by burning the hydrureted metal ; if it be arsenic, the usual indications are obtained, very different from those given by the oxide of antimony.

1363. Lastly, in applying this test, the extremely deleterious nature of the arsenureted hydrogen should be particularly remembered, as fatal consequences may follow from even small portions being taken into the lungs (1372.) The zinc and sulphuric acid employed in preparing the hydrogen gas for dissolving the arsenic must also be particularly examined, as

they are frequently contaminated with arsenic. The simplest method of proceeding consists in preparing hydrogen with them in the above apparatus, and testing it for arsenic in the manner recommended by Liebig. Or the sulphuric acid, when it is suspected to contain arsenic, may be diluted with water, and a stream of hydrosulphuric acid gas passed into it, proceeding afterwards in the manner shewn in 1349, &c.

1364. If a quantity of solid powder be obtained among the contents of the stomach, the following experiments may be made.

1365. Expose a small quantity to heat on a thin plate of copper over a spirit-lamp ; it will be completely volatilized if it be arsenious acid. Mix another portion with twice its weight of charcoal recently ignited, and if a crust be obtained which has the character of metallic arsenic, it will be unnecessary to proceed any further. Should the appearance of the crust be unsatisfactory, it must be treated in the manner described in 1353, and if no indication of arsenious acid be then obtained, we may conclude that the white powder does not contain any.

1366. Many other methods of detecting the presence of arsenious acid have been proposed, but none of them are so important as those already described, with the exception of one, lately pointed out by Mr E. Davy, which promises to be of great value. This consists in placing any liquid suspected to contain it on a piece of platinum, and touching it then with a piece of zinc ; metallic arsenic is immediately deposited upon the platinum, should the liquid contain any, and Mr Davy states that he was enabled to detect the presence of arsenic, shewing its characteristic properties, with the 500th part of a grain precipitated in this manner. This method of operating has already been described for the detection of lead and copper.

1367. Arsenic Acid. . (*Symb.* O^5As^2, *or* $::As^2$; *Eq. by W.* $115.4 = O.40 + 75.4$ As.) This compound is prepared by digesting metallic arsenic or arsenious acid in strong nitric acid, evaporating the solution afterwards to dryness in a glass or earthen vessel. The process proposed by Scheele consists in dissolving three parts of arsenious acid in seven of hydrochloric acid by the assistance of heat, after which five parts of nitric acid are to be added, and the liquid evaporated to dryness ; the residue may then be heated to dull redness in a crucible. A much less quantity of hydrochloric acid is considered sufficient. Bucholz

recommends 2 of hydrochloric acid, 8 of arsenious acid, and 24 of nitric acid.

1368. If equal parts of nitre and arsenious acid are fused in a crucible, the nitric acid is completely decomposed, part of the arsenious acid attracting oxygen from it and being converted into arsenic acid, which remains in combination with the potassa, while the rest is volatilized. The arseniate of potassa is speedily dissolved on digesting it in water ; it gives a brick-red precipitate with a solution of the nitrate of silver. Mix half a grain of arsenious acid with an equal weight of nitre, fuse it slowly in a platinum spoon over a spirit-lamp, then put the spoon into a test-tube with a little water, and add a drop of a solution of the nitrate of silver to the solution of arseniate of potassa obtained in this manner, when the characteristic brick-coloured precipitate will be thrown down. When arsenious acid is mixed with organic matter, it is often advantageous to heat it in this manner with nitre, as the oxygen of the nitre completely decomposes the organic matter, after which, the arsenic acid that is formed may be detected in the usual manner by nitrate of silver.

1369. Arsenic acid thus procured is a white solid, having a sour, somewhat metallic taste ; and is very deliquescent. By a full red-heat, it is reduced to arsenious acid, oxygen being expelled. It reddens vegetable blues, decomposes alkaline carbonates with effervescence, and combines with the alkalis, forming *arseniates*. It is very soluble, dissolving in six parts of cold water, and much less (about two parts) of boiling water. It does not crystallize from its evaporated solution, but forms in a granular powder. At a certain stage of the evaporation it forms a jelly. Its solution is very sour, even when considerably diluted. It is considered as noxious as arsenious acid, or more so.

1370. HYDRURET or PROTOHYDRURET of ARSENIC. This is a solid compound, which may be formed by different processes. By the action of water on an alloy of potassium and arsenic, the alloy is decomposed, and also some water, the oxygen uniting with the potassium, while the arsenic combines with the hydrogen, and forms the hydruret.

1371. SESQUIHYDRURET of ARSENIC (commonly called ARSENURETED HYDROGEN). *Symb.* $H^3 As^2$. *Eq. by W.* 78.4 =

H. 3 + 75.4 As. This compound is usually prepared by digesting an alloy of tin and arsenic in liquid hydrochloric acid. A portion of water is decomposed, the tin uniting with its oxygen and forming oxide of tin, which remains in solution combined with the hydrochloric acid, while the hydrogen and arsenic unite and escape in the gaseous form. Or, it may be supposed that the acid is decomposed, yielding chlorine to the tin, which is then formed into chloride of tin which remains in solution, while the hydrogen passes to the arsenic and forms the gas. Procured in this manner, it is said to contain free hydrogen. It is considered to be free from this gas when formed by the action of concentrated hydrochloric acid on an alloy prepared by melting together equal weights of arsenic and zinc. Its purity is ascertained by passing it through, or agitating it with, a strong solution of sulphate of copper, which absorbs the arsenureted hydrogen and leaves all the hydrogen.

1372. This is a very deleterious gas; it proved fatal to Gehlen, a German chemist, in 1815. It is colourless, has an offensive odour, burns with a blue flame when a light is applied to it, extinguishes burning bodies immersed in it, and is instantly fatal to any animals placed in it. If it be supplied with little air during its combustion, metallic arsenic is deposited; if exploded with sufficient oxygen, arsenious acid is produced. Water absorbs about one-fifth of its bulk of this gas. Chlorine decomposes it, uniting with the hydrogen, and eliminating metallic arsenic, heat and light being evolved. Strong nitric acid decomposes it, red fumes being given off, flame and an explosion sometimes accompanying the action. When chlorine is added to a mixture of hydrosulphuric acid and arsenureted hydrogen gases, a diminution in bulk ensues, and flakes of yellow sulphuret of arsenic are deposited.

1373. SULPHURET of ARSENIC (PROTOSULPHURET, RED SULPHURET, or REALGAR). *Symb.* SAs. *Eq. by W.* 53.8 = S. 16.1 + 37.7 As. This compound may be obtained by mixing arsenious acid with two-fifths of its weight of sulphur, and exposing the mixture to heat in a covered crucible till it is fused; part of the sulphur unites with the oxygen and forms sulphurous acid, which is disengaged, and the rest unites with the metallic arsenic, forming the deep red-coloured mass that remains. It is sublimed when exposed to heat in a retort, and condenses

in the neck in the form of a very rich red-coloured powder.   It
occurs native.

1374. Realgar has been used as a pigment. It is employed in
the mixture for the white light, called *White Indian* Fire. The
following proportions are recommended for this mixture, 24 of
nitre, 7 of flowers of sulphur, and 2 of realgar.   They must
be reduced to a fine powder, and thoroughly mixed.

1375. SESQUISULPHURET of ARSENIC (called also YELLOW
SULPHURET, ORPIMENT).   *Symb.* S^3As^2.   *Eq. by W.* 123.7 =
S. 48.3 + 75.4 As.   This compound contains more sulphur than
the red sulphuret.   It may be prepared in the same manner, from
a mixture of *equal weights* of sulphur and arsenious acid.   It is
the compound precipitated when hydrosulphuric acid gas is
transmitted through a solution of arsenious acid.   It occurs na-
tive, of a brilliant yellow, formerly called *auripigmentum*.   It is
employed as a pigment, known under the name of *King's Yel-
low.*

1376. The sesquisulphuret of arsenic is of a fine yellow co-
lour.   It is insoluble in water, but if exposed when in a minute
state of division to the action of this liquid for some time, it is
gradually decomposed, and arsenious acid is found in solution.
It is readily dissolved by alkalis.   It is easily fused by heat, and
presents a somewhat crystalline texture when cool.   Heated
out of contact of air, it may be sublimed, and condenses unal-
tered.

1377. Orpiment is employed in calico-printing to deoxidate
indigo, which is thus rendered soluble and enabled to penetrate
the cloth.   It has also been used as a yellow dye.   For this pur-
pose, Braconnot recommends 1 part of sulphur, 2 of arsenious
acid, and 5 of pearl ash, to be fused in a crucible at a tempera-
ture a little below a red-heat; the mass to be lixiviated and the
solution filtered; diluted sulphuric acid to be poured into the
filtered solution, and the yellow precipitate of orpiment thus
thrown down to be dissolved in ammonia, adding an excess of
the alkali.   Cloths soaked in this solution become of a fine yel-
low colour as they dry, the ammonia evaporating, and the orpi-
ment being precipitated upon the cloth.

1378. A PERSULPHURET of ARSENIC, containing more sulphur
than either of the preceding compounds, may be procured by the
action of hydrosulphuric acid gas on a solution of arsenic acid.

Berzelius has pointed out another sulphuret of arsenic, in which one eq. of arsenic is combined with nine of sulphur.

1379. SESQUICHLORIDE of ARSENIC. Throw some metallic arsenic reduced to powder into a bottle of chlorine gas. The arsenic immediately takes fire, and a sesquichloride is formed. It may also be procured by distillation from a mixture of one part of metallic arsenic, with six of bichloride of mercury. It is a liquid, very volatile, and fuming in air, formerly termed *butter of arsenic*, or *fuming liquor of arsenic*.

1380. The compound procured by distilling one part of arsenious acid with ten times its weight of sulphuric acid, adding newly fused common salt from time to time, is considered by Dumas as a chloride (protochloride) of arsenic.

CHAP. XII.—NICKEL, &c.

Symb. Ni. *Eq. by W.* 29.5. *Sp. gr.* 8.2 to 8.8. *Its fusing-point is a little lower than that of manganese. It is attracted by the magnet.*

1381. This metal is not very abundant. It exists in most specimens of meteoric iron, but chiefly in a reddish ore termed *Kupfer-nickel*, or copper-nickel. The metal may be procured from this ore by roasting it, by which sulphur and arsenic are expelled, mixing the residuum with twice its weight of black flux, and exposing it to a very high temperature. The nickel prepared in this manner is very impure, containing cobalt, copper, and iron. A purer nickel may be obtained by the following process, recommended by Dr Thomson. The SPEISS employed is an *arseniuret of nickel*, containing also cobalt, copper, antimony, sulphur, and some earthy matters. It is left at the bottom of the crucibles in which *zaffre* is prepared.

1382. Reduce to powder a quantity of speiss, and boil it in diluted sulphuric acid till it is dissolved, adding small quantities of nitric acid from time to time to promote the oxidation ; a deep green-coloured liquid is obtained in this manner, containing sulphate of nickel in solution, which must be separated carefully from any insoluble matter that may be mixed with it, and

B b

allowed to remain at rest for several hours, that arsenious acid may be deposited. It is then to be mixed with sulphate of potassa in solution, and crystals of sulphate of potassa and nickel formed by spontaneous crystallization. These must be dissolved in water, and a stream of hydrosulphuric acid gas is to be passed through the solution, to separate any copper which it may contain. Then boil the solution that remains, and precipitate the oxide of nickel along with any oxide of cobalt by potassa. Wash the precipitate, and pass a stream of chlorine through it while still moist and suspended in water : the cobalt which it contains, and also a portion of the nickel, pass to the state of peroxide and are not dissolved, but the solution contains chloride of nickel. Oxalate of ammonia precipitates, after some time, oxalate of nickel : and, by heating this in a crucible, metallic nickel is obtained in the form of an ash-coloured powder. By exposing it to a very high temperature it is melted.

1383. Nickel is of a white colour, with a fine metallic lustre, resembling silver. It possesses considerable ductility and malleability. It is not altered by exposure to air or water at ordinary temperatures. When heated to redness, it is oxidated, either in air, or in watery vapour. The nitric and nitro-muriatic acids are the best solvents of this metal. Sulphuric acid has little action upon it, but combines readily with the oxide that is formed on adding a little nitric acid.

1384. Nickel is an ingredient in the *white copper* of the Chinese, and in the composition now so much used called *German silver.* See Alloys.

1385. OXIDE OF NICKEL may be obtained by heating the nitrate or carbonate of nickel to redness in an open crucible. Its colour is grey, and the most of its salts have a green colour. It is precipitated as a hydrate by alkalis. Heated to redness the water is expelled.

1386. PEROXIDE OF NICKEL may be prepared by transmitting chlorine through water in which the oxide is diffused in fine powder; a portion of this liquid is decomposed, the hydrogen combining with the chlorine, and the oxygen with part of the oxide of nickel, converting it into peroxide, which is left undissolved.

1387. Solutions of salts of nickel have a fine green colour, and give an apple-green precipitate with a solution of potassa. Am-

monia precipitates the oxide of nickel, and by an excess of this agent it is redissolved, forming a solution of a blue colour, similar to, but not so rich as that produced with copper. They are not precipitated by hydrosulphuric acid alone, but an alkaline hydrosulphate gives a dark-coloured precipitate. The ferrocyanate of potassa gives a greyish-white precipitate.

The following metals, usually classed along with those immediately preceding, being rarely made the subject of experiment by the beginner, are very briefly noticed in this place.

1388. CADMIUM (*Symb.* Cd ; *Eq.* 55.8 ; *Sp. gr.* 8.6). Similar in appearance to tin, ductile and malleable ; volatilized a little above the boiling point of mercury, condensing in globules as it cools. Oxidated on exposure to heat and air, the oxide being fixed. Nitric acid is its best solvent.

1389. Precipitated as a sulphuret from solutions of its ores on acidulating them, and passing through them a stream of hydrosulphuric acid. Nitric acid dissolves the sulphuret, and forms a solution from which the carbonated oxide may be precipitated by carbonate of ammonia. The carbonic acid may be expelled by a red-heat, and the oxide left affords cadmium by sublimation when heated with charcoal.

1390. MOLYBDENUM (*Symb.* Mo ; *Eq.* 47.9 ; *Sp. gr.* 8.6). Very brittle, of a white colour, imperfectly fused, even with a very intense heat. Combines with oxygen in different proportions, forming oxides and an acid.

1391. Prepared in general from the sulphuret of molybdenum, by digesting it in nitro-muriatic acid till it is resolved into molybdic acid, expelling sulphuric acid formed during this operation by a sharp heat, and heating the molybdic acid afterwards in a smith's forge, having previously mixed it with charcoal in a very minute state of division. The oxygen of the acid is removed by the carbon as the metal is reduced.

1392. TUNGSTEN or WOLFRAM (*Symb.* W ; *Eq.* 94.8 ; *Sp. gr.* 17). Tungsten is a brittle metal, having a greyish-white

colour, with considerable lustre, and great hardness.　It burns when heated and exposed to the air, producing tungstic acid. Nitric acid produces the same compound.　Prepared from tungstic acid, by heating it powerfully with charcoal.　Tungstic acid is procured from the tungstate of lime by nitric acid and ammonia acting alternately, the former removing the lime, and the latter dissolving the tungstic acid ; the ammonia is expelled subsequently by heat.

1393. VANADIUM (*Symb.* V. *Eq.* 68.5) is usually obtained in the form of a black powder, which assumes a greyish colour and feeble lustre when strongly compressed.　Prepared with greatest facility from the vanadiate of lead, as recommended by Professor Johnston.　The ore is dissolved in nitric acid, and the lead, along with any arsenic that may be present, is precipitated by hydrosulphuric acid.　The vanadic acid is at the same time reduced to an oxide, and the solution becomes blue; the vanadic acid is restored again, however, when the liquid is evaporated to dryness.　By the action of ammonia, vanadiate of ammonia is procured, and if a mass of hydrochlorate of ammonia be introduced so as to produce a saturated solution, vanadiate of ammonia is deposited, from which the ammonia is expelled by heat.　Vanadium is then obtained from the acid by heating it with potassium, as Berzelius at first recommended, or more conveniently, by passing ammoniacal gas over the chloride of vanadium, metallic vanadium being left, hydrochlorate of ammonia formed (which may be expelled subsequently by heat), and nitrogen gas evolved, as part of the ammonia gives hydrogen to the chlorine and forms hydrochloric acid.

1394. URANIUM (*Symb* U.　*Eq.* 217.2.　*Crystalline texture, reddish-brown colour, absorbs oxygen when heated in the open air*). Procured from a dark-coloured mineral composed principally of oxides of uranium and iron.　By digesting it in great excess in nitric acid diluted with water, nitrate of the peroxide of uranium was procured in solution, the iron being left undissolved.　The properties of metallic uranium are very imperfectly known.

1395. TITANIUM (*Symb.* Ti.　*Eq.* 23.5).　This metal, as prepared by Leibig, was procured in the form of a deep blue-coloured powder.　He obtained it by passing over the chloride of titanium and ammonia a current of dry ammoniacal gas,

applying, after the atmospheric air had been expelled, as much heat as the glass tube containing the chloride would admit. Nitrogen gas is evolved, and hydrochlorate of ammonia is separated at the same time, the metallic titanium being left in the tube.

1396. The chloride of titanium and ammonia is procured by exposing the bichloride to the action of ammonia, when a large quantity of this gas is absorbed. The bichloride is formed by heating to redness titanium, or a mixture of titanic acid and charcoal, and passing chlorine gas over it.

1397. Titanium has attracted considerable notice in consequence of its being found in crystals in the slag from a number of iron-works. They are extremely hard, very infusible, and resemble in some degree, in many of the specimens I have seen, imperfectly crystallized bismuth.

1398. TELLURIUM (*Symb.* Te. *Eq.* 64.2. *Sp. gr.* 6.25). Brittle, lamellated, of a highly metallic lustre, and a greyish-white colour with a shade of blue. Melts below redness, and volatilized by a higher temperature. Exposed to heat and air, it burns with a bluish green-coloured flame. With oxygen it forms two acids, the tellurous and telluric, and with hydrogen it produces a gaseous compound, the hydrotelluric acid, similar to the hydrosulphuric acid.

1399. Tellurium occurs principally in combination with gold and silver.

1400. CERIUM (*Symb.* Ce. *Eq.* 4.6. *White and brittle, volatilized by intense heat, and soluble in nitro-muriatic acid.*) Procured from cerite and allanite, the principal minerals in which it has hitherto been discovered.

1401. COLUMBIUM or TANTALUM (*Symb.* Ta. *Eq.* 184.8). Colour grey, lustre metallic after compression, but usually obtained at first in the form of a black powder. Prepared by Berzelius on heating the fluoride of potassium and columbium with potassium, fluoride of potassium being then removed by water, and the columbium left. In most of its ores, it is combined with much oxygen, in the form of columbic acid, being also associated with yttria, iron, or manganese. By fusion with a fixed alkali, it is removed as a soluble columbate, the columbic acid being precipitated on the addition of a stronger acid.

II. COMMON METALS WHOSE OXIDES CAN BE RE-DUCED BY EXPOSURE TO HEAT WITHOUT INFLAMMABLE MATTER.

CHAP. I.—MERCURY (or QUICKSILVER).

Symb. Hg. *Eq. by W.* 203. *Sp. gr.* 13.5. *It becomes solid at* —39.5°, *and is volatilized at* 650°.

1402. Mercury occurs native, but is rare. It is procured from the ore termed *native cinnabar*. a bisulphuret. Mix four or five ounces of the native or prepared bisulphuret of mercury with an equal weight of lime or iron-filings, throwing an additional quantity of lime or iron over the mixture, and expose it for an hour or two to a dull red-heat in an iron-retort, or in an iron-bottle with a bent gun-barrel or other iron-tube adapted to it. The sulphur is withdrawn by the iron or the lime, and metallic mercury is disengaged, being slowly volatilized, and condensing in drops in the iron-tube, the open extremity of which should be put into water.

1403. This process may be imitated on a still smaller scale, by mixing twenty or thirty grains of the bisulphuret with as much iron-filings, and exposing them to heat in a glass-tube, holding the part containing the mixture in a horizontal posi-tion over a spirit-lamp, or placing it on the top of a chauffer, and surrounding it with small pieces of charcoal. I find a chauffer with a piece cut out at the top of one of the sides ex-tremely convenient for performing a number of experiments like this on the small scale, the tube resting on the edge, and being supported within the chauffer by the fuel, and without, by a brick or piece of wood; a figure of a tube placed in this

manner is given in the chapter on Tube-Apparatus. The temperature can be easily regulated; if the mixture is to be exposed only to a moderate heat, it will be unnecessary to surround the tube with charcoal, but if it is to be subjected to a high temperature, then the tube must be coated in the manner described in par. 357, and completely covered with a mixture of small cinders and pieces of charcoal, and a chimney should be put over the chauffer (11.), which may be prolonged if necessary by another tube of nearly the same diameter fitted to the top. The size of the glass-tube must correspond with the quantity of materials used; it need not be larger than the tube employed for the reduction of arsenic, or it may be an inch in diameter, and ten or twelve inches long. The mixture should not occupy more than one or two inches of the sealed end of the largest size of tubes; and the tube should always be placed in an inclined position, so that any watery vapour which may be disengaged and condensed on the side may not fall back upon the hot part of the tube, otherwise it will be broken.

When a very small quantity of materials is used, the metallic globules are not seen very distinctly at first, but if the matter that is sublimed be taken out and rubbed gently on a dry plate with a piece of paper, metallic globules will become apparent.

1404. When the materials are not well mixed, or when the heat is incautiously applied, a good deal of the bisulphuret is sublimed without decomposition, and is very apt to obstruct the tube, condensing principally a little way beyond the part to which the heat is applied. As serious accidents might take place from the accumulation of vapour when there is no opening by which it may escape, the student cannot be too cautious in attending to this circumstance in making experiments of this kind, especially in narrow glass-tubes; when the temperature, however, is sufficiently high to soften the glass, no danger need be apprehended, as the glass will then be slowly blown out by the vapour within, till some part of it gives way and allows it to escape.

1405. An iron-tube closed at one end by welding, as a piece of a gun-barrel, or an earthen tube closed with some clay or plaster of Paris, may be used instead of a tube made of glass.

1406. In this process, supposing iron alone to be used, it combines with the sulphur of the bisulphuret of mercury, forming

sulphuret of iron, while metallic mercury is disengaged. The following diagram gives the most probable view of the atomic proportions in which the materials act upon one another, though I am not aware that this has been minutely examined.

Fig. 206.

Before Decomposition.   *After Decomposition.*

235.2 Bisulphuret of { Mercury 203 ---------- 203 Mercury.
Mercury ...... { Sulphur 16.1
              { Sulphur 16.1
Iron............................. 28————44.1 Sulphuret of Iron.
Iron............................. 28————44.1 Sulphuret of Iron.

Symb. S^2Hg & $2 Fe = Hg$ & $2 SFe$.
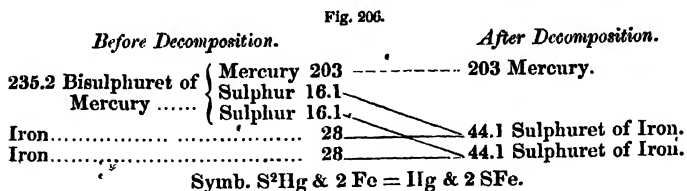
1407. Metallic mercury being frequently adulterated with a considerable quantity of other metals, such as lead, tin, zinc, and bismuth, it will be necessary to attend to the characters by which it may be distinguished when pure, and the method of purifying it from any foreign matter with which it may be adulterated.

1408. Pure mercury has a bright white metallic lustre, and appears extremely mobile when poured from one vessel to another or thrown upon a level surface, the globules in the latter case being round, having a very high edge, and being easily divided into a number of smaller globules, all of which appear equally mobile. It does not tarnish on exposure to the air, no film collects on its surface when shaken in a bottle, and, when exposed to heat, it is completely volatilized.

1409. When mercury has acquired a crust of oxide from the action of acid fumes, or when a quantity of dust has collected on its surface, it is easily purified by folding a piece of writing-paper into a cone, leaving a small aperture at the bottom about the size of the point of a pin, or a little larger, and pouring the mercury into this cone, supported in a glass-funnel; the pure mercury passes through in a very slender stream, and the greater portion of the dust and oxide remains on the sides of the cone. A small quantity of mercury always remains at the bottom of the cone; it should not be forced through and mixed with the rest, but should be set aside by itself or with other portions of impure mercury. When a large quantity of mercury is to be filtered in this manner, fresh portions should be poured into the filter from time to time, before what has already been put in

ceases to drop, otherwise part of the dust or oxide is forced through along with the mercury. The vessel into which the mercury is received should be perfectly dry, otherwise it may not appear so pure as it really is, moisture preventing the globules that first fall through from coalescing so easily together.

1410. If the mercury be adulterated with any of the metals we have mentioned, it has not that bright metallic appearance which pure mercury always presents, a film soon collects on its surface, and another appears whenever this is removed. It is not nearly so mobile as pure mercury ; when a small quantity is thrown on a flat surface, it does not divide so readily into globules, and they are not so round, but have an irregular appearance, and their edges, instead of being high and prominent, are nearly on a level with the surface on which they rest. When it is loaded with impurities, it presents more the appearance of a soft solid than of a liquid.

1411. To separate these, the usual process is to distil it in an iron-bottle with a bent iron-tube adapted to it. The Edinburgh College directs the mercury to be mixed with a sixth part of its weight of iron-filings, and the mercury is obtained in a purer state in this manner than when it is distilled without any admixture. The effect of the iron in this process is not very well understood ; it has no great affinity for any of the other metals with which mercury is usually adulterated. Perhaps it acts principally by allowing the mercury to be converted more easily into vapour, and in smaller quantities at a time, lessening the risk of any being carried over mechanically during the ebullition ; it is known that water and other liquids can be made to boil several degrees below their usual boiling point, in glass or porcelain vessels, by introducing some pieces of wire or other solid matter, and that thus a constant stream of vapour may be made to arise from them, instead of the liquid entering only occasionally into a state of violent ebullition, and then ceasing for a short time to give any more vapour, till it is produced again with violence as before. Advantage is taken of this in the distillation of impure sulphuric acid, and it is probable, that, in the distillation of impure mercury, the other metals which are mixed with it may have a greater tendency to pass over, either in vapour or mechanically suspended, when the distillation is conducted without the assistance of the iron-filings.

Dr Faraday recommends copper-filings to be mixed with the iron-filings.

1412. In all cases the distillation should be conducted with a very gentle heat, and the materials should never fill more than a third of the retort or bottle in which it is carried on ; the extremity of the tube should be made to dip under water, and ought to be taken out when the last portions of mercury have passed over. For distilling large quantities of mercury, one of the iron bottles in which it is sold will do extremely well, fitting a bent gun-barrel accurately to it by grinding. It may be heated by an open fire, placing it on a piece of brick or on several bars of iron laid across each other, to raise it an inch or two above the grating, surrounding it about half-way up with burning fuel (a mixture of charcoal and cinders should be used), and taking care to moderate the heat whenever it begins to boil.

1413. Iron-filings, as they are usually procured, are mixed with a little oil ; this is decomposed during the distillation, and a small quantity of an empyreumatic oil passes over with the metallic mercury and condenses in the water, often preventing the globules from uniting together, so that they assume the appearance of a soft solid. When this takes place, the water should be poured off and a small quantity of a solution of caustic potassa be poured over them ; this removes the oil, and on washing them with water, they readily unite, after which they should be passed through a paper filter (1409).

1414. Though mercury is obtained sufficiently pure for ordinary experiments by distilling it cautiously in the manner that has been described, still it frequently contains a small portion of zinc. This may be removed by shaking it with diluted nitric acid in a bottle, and then pouring both into a plate, where they may be left together for a few days, after which the mercury must be washed and filtered as before ; the acid may be diluted with ten or twelve parts of water.

1415. When only a small quantity of mercury is to be purified, as an ounce or a pound, Dr Priestley's method will be found most convenient. It consists merely in shaking the mercury briskly in a bottle capable of containing four or five times its bulk, blowing into it occasionally with bellows to renew the air, and continuing till a black matter gathers together, which may be easily separated from most of the metallic mercury by

a paper funnel ; after this, it should be returned again, and the operation should be repeated till no more oxidation takes place, when the mercury becomes extremely clean and mobile, the brightening taking place all at once as the last portions of the other metals are oxidated.

1416. A tolerably pure mercury may be obtained by distillation in an earthen retort from a mixture of two parts of artificial cinnabar, and one of iron-filings, at a heat approaching to redness.

1417. OXIDE OR PROTOXIDE OF MERCURY, called also Black or Ash-Coloured Oxide of Mercury. (*Symb.* OHg, or ·Hg. *Eq. by W.* $211 = 0.8 + 203$ Hg.) This compound is prepared most easily by mixing calomel (chloride of mercury) with a solution of potassa in a mortar, rubbing them together for a quarter of an hour or twenty minutes, and taking care to have an excess of alkali, that the decomposition may be complete. For every equivalent of the chloride employed, a corresponding quantity of fused potassa may be taken and dissolved in two or three ounces of water, allowing the solution to stand till it becomes clear, when it may be decanted for use. A slight excess of alkali is preferred, so that no chloride may be left undecomposed. Hydrochlorate of potassa remains in solution, and the oxide may be separated by filtration, washing it with cold water, and keeping it in a dark place, as it soon begins to be decomposed on exposure either to heat or light, one portion losing oxygen, which combines with another, so that small quantities of metallic mercury and binoxide of mercury are then found to be mixed with the oxide.

1418. Instead of using a solution of potassa, the Edinburgh College prepare their oxide from chloride of mercury (formerly called Submuriate of Mercury) by lime water. The same reaction takes place as when potassa is used; half an ounce of the chloride may be used with every five pounds of lime water, boiling them together for a quarter of an hour after rubbing them together in a mortar ; a small quantity of the lime water should be mixed at first with the dry powder, that it may be quickly moistened. Hydrochlorate of lime remains in solution, and the oxide must be washed on a filter with distilled water ; the following diagram shews more precisely the nature of the reaction.

Fig. 207.

Before Decomposition.			*After Decomposition.*
28.5 Lime............................28.5			65 Hydrochlorate of Lime.
9 Water .... {	Hydrogen	1	
	Oxygen	8	
238.5 Chloride of {	Chlorine	35.5	
Mercury ...... {	Mercury	203	211 Oxide of Mercury.

1419. The oxide of mercury may be obtained also by adding a solution of potassa or soda to a solution of the nitrate of mercury ; the alkali unites with the acid, while the oxide is precipitated.

1420. By triturating metallic mercury with chalk, manna, sugar, lard, and a number of vegetable and animal substances, the metallic globules disappear, and a mass is obtained of a dark colour ; many consider the metallic mercury to be merely reduced to a very minute state of division in this manner, while others affirm that it is at the same time oxidated. Some experiments by Mitscherlich support the opinion that the mercury is in general merely in a minute state of division. Mr Phillips mentions that the mercury which is prepared with chalk contains a small portion of the binoxide of mercury.

1421. When the oxide of mercury is quite pure, it has a dark colour, and is completely dissolved by acetic acid, but is quite insoluble in hydrochloric acid. It is very readily decomposed.

1422. BINOXIDE or PEROXIDE of MERCURY, termed more familiarly RED PRECIPITATE. (*Symb.* O²Hg, or :Hg. *Eq. by W.* 219 = O.16 + 203Hg.) This substance may be obtained by dissolving three parts of metallic mercury in four of diluted nitrous acid (made by mixing equal weights of water and the strong acid prepared in the manner described in par. 191), evaporating the solution to dryness, and then reducing it to powder and exposing it to a stronger heat in an evaporating basin over a good chauffer, till it assumes a deep red colour. It should be covered by a flat plate, which may be removed from time to time to allow the progress of the decomposition to be observed ; a large quantity of ruddy fumes are disengaged, which cease to come when all the powder has acquired a dark colour, after which it must be removed from the fire, otherwise it is resolved into metallic mercury and oxygen gas. As it cools, it assumes a bright red colour, and the lowest portion is usually obtained in the form of brilliant scales, this appearance depending probably on the

pressure of the superincumbent mass, as it is always seen more distinctly the larger the quantity of binoxide prepared.

1423. In this process, the metallic mercury decomposes part of the nitric acid, and is converted into binoxide of mercury, which combines with the remainder of the acid, so that the dry mass which is obtained in the first stage of the process is a compound of nitric acid and the binoxide of mercury. The nitric acid is afterwards almost entirely expelled, being resolved by the heat into nitrous acid and oxygen gases. The quantity of nitric acid that remains in combination with the binoxide is extremely small.

1424. Another method of preparing binoxide of mercury consists in exposing metallic mercury to air at a temperature between 500° and 600°, when it combines slowly with oxygen and is converted into red scales; these were formerly called *Precipitate per se*, and are larger than those procured by the decomposition of the nitrate; they have not the same shining appearance, however, and, not containing any nitric acid, they are not so acrid. As upwards of a fortnight is required to prepare a few grains of binoxide in this manner, it is a process that is seldom resorted to.

1425. Binoxide of mercury may also be obtained, according to the formula of the London College, by the action of a solution of potassa upon the bichloride of mercury, two eqs. of hydrochlorate of potassa remaining in solution for every eq. of binoxide precipitated.

1426. Binoxide of mercury is occasionally adulterated with oxide of lead, which may be easily detected by exposing it to heat on charcoal before the blowpipe. If the binoxide be pure, it is completely dissipated, oxygen gas being disengaged, and the metallic mercury being volatilized; if, however, any oxide of lead should have been mixed with it, a globule of metallic lead remains on the charcoal. If it be purchased in the form of scales, it is generally obtained perfectly pure, and any foreign admixture can often be easily detected by bare inspection, but when it has been reduced to an impalpable powder, it may then be suspected to have been adulterated.

1427. Many tests have been proposed for detecting mercury in solution; the more important of these are mentioned in the succeeding paragraphs.

1428. One of the most delicate tests is that proposed by Mr Sylvester. A drop of the liquid suspected to contain it is to be placed on a piece of gold-leaf, or any piece of solid gold, and the point of a nail, or penknife, or of any small piece of iron, is to be placed in contact with the moistened surface ; if any mercury be present, the gold immediately becomes white where it is touched by the other metal, uniting with the mercury, and forming a solid amalgam, which retains its white colour after the fluid has been wiped off.

1429. Mr Smithson's mode of operating consists in immersing a gold plate or ring in the solution, after adding a few drops of hydrochloric acid to it, and putting a piece of tin foil round the gold ; the mercury is immediately deposited on the gold, and, on exposing the gold to heat, it regains its original colour, the mercury being volatilized. Orfila has observed, however, that all these appearances may be obtained by operating in the manner described, with solutions containing no mercury, part of the tin being dissolved by the acid and afterwards precipitated upon the gold, communicating a white stain which disappears on the application of heat ; and though the precipitate may be distinguished by strong hydrochloric acid, which dissolves tin but not mercury, he considers it better to heat the gold in a small glass-tube, when any mercury that may have been precipitated upon it is volatilized, and condenses in globules in the upper part of the tube. Mr E. Davy has employed platinum and zinc to detect mercury in solution, proceeding in the manner described in 1084, page 312, for the detection of lead.

1430. Put a piece of bright copperplate into a solution of any salt of mercury ; part of the copper is dissolved, combining with the oxygen of the oxide of mercury, and with the acid with which it was previously united, while an equivalent quantity of metallic mercury is precipitated ; part of the metallic mercury amalgamates with the copper, and, when the copper is introduced into a solution of bichloride of mercury, a portion of chloride of mercury is also thrown down.

1431. Immerse a plate of tin in a solution of the bichloride of mercury ; it is immediately tarnished, mercury being deposited upon it. When the surface is scraped with a knife, and the scrapings are heated in a tube, metallic mercury may be

obtained, even when a very small quantity has been precipitated upon the tin.

1432. Add a solution of the chloride of tin to a solution of a salt of mercury ; a grey-coloured precipitate is thrown down. After washing it repeatedly with boiling water, and drying and heating it gently, metallic globules of mercury are seen, unless the quantity should be very minute, and then they may in general be made to appear by heating the precipitate in a tube, so as to volatilize the mercury, which condenses in a cold part of the tube.

1433. Add potassa in solution to a solution of a salt of mercury ; oxide of mercury is immediately precipitated. If the mercury in the liquid shall have been in the form of oxide, the precipitate is of a dark colour, but when it contains the binoxide alone, the precipitate is yellow or red. Collect the precipitate on a filter, dry it, and expose it to heat at the bottom of a small test-tube over a spirit-lamp, when, globules of metallic mercury are seen.

1434. Put a small quantity of a solution of a salt of the oxide of mercury into a glass, and fill it up with lime water ; oxide of mercury will be immediately thrown down, and give a dark colour to the liquid.

1435. Into another glass, put a similar quantity of a solution of a salt of the binoxide of mercury, and add lime water as before ; a yellow precipitate appears, which becomes red, and afterwards again appears yellow as the lime water continues to be added.

1436. Add some hydrosulphate of ammonia to a diluted solution of a mercurial salt; a copious black precipitate is thrown down, consisting of sulphur and mercury, probably in combination with water.

1437. If a stream of hydrosulphuric acid gas be passed through a solution containing mercury, the precipitate that is thrown down at first consists of sulphuret of mercury, and of mercury united with the acid, or other solvent of the mercury, in the solution employed (Rose). The precipitate is white at first, as when a solution of the bichloride of mercury is acted upon, but it becomes black when a sufficient quantity of the gas is passed through it, all the mercurial compound at first precipi-

tated in combination with the sulphuret being at length entirely decomposed.

1438. A solution of the ferrocyanate of potassa gives a white precipitate with salts of mercury.

1439. Hydrochloric acid and solutions of the hydrochlorates, added to salts of the oxide, give a white precipitate, composed of ·chloride of mercury.

1440. All the salts of mercury are completely decomposed or volatilized by exposuie to a dull red-heat, and metallic mercury may be, obtained by heating them with a little potassa or soda in a glass-tube.

1441. In examining mixed fluids' suspected to contain bichloride of mercury in solution, ẛs in cases of poisoning, it must be recollected that manÿ vegetable and animal substances decompose bichloride of mercury, combining both with chlorine and mercury, and forming a peculiar combination which is precipitated. Dr Christison, in his treatise on poisons, gives a detailed account of the more important circumstances known in regard to this decomposition, and has proposed the following method of operating with precipitates such as these, a mode which ought always to be resorted to when the suspected solution, on the addition of chloride of tin, gives no precipitate, or a very feeble one, indicating the, presence of mercury in the liquid in which they are contained.

1442. Remove all fibrous vegetable matter from the liquid, as pieces of seeds and leaves ; then add a solution of the chloride of tin (protochloride), as long as any precipitate or coagulum is formed. Drain it on filtering paper, and remove it while still moist, taking care not to carry along with it any fibres of the paper ; boil it in a glass-flask with a moderately strong solution of potassa till the solid matter disappears, and allow the solution to remain at rest, that any heavy greyish-black powder may fall down, which soon appears should there have been any mercury present. It is composed of metallic mercury, and should the globules not be seen distinctly, they may be obtained by washing and drying the precipitate, subliming it afterwards in a tube.

1443. Should the mixed liquid under examination, however, give a very distinct greyish-black coloured precipitate with the chloride of tin, a different process may be resorted to. Agitate

it for a few minutes with one-fourth part of its volume of sulphuric ether ; it removes any bichloride which the liquid may contain, and rises soon to the top, from which it may be removed by a pipette. Evaporate to dryness, and dissolve in water ; the appropriate tests now indicate the bichloride in solution.

1444. Among the animal substances which decompose bichloride of mercury, albumen is pre-eminently distinguished, and is the antidote recommended in cases of poisoning by this substance.

SALTS OF MERCURY ; CHLORIDES, IODIDES, AND SULPHURETS OF MERCURY, &c.

1445. NITRATE OF MERCURY (protonitrate) may be obtained by digesting metallic mercury for a short time with a very gentle heat in diluted nitric acid (prepared by mixing one part of acid with four of water), allowing the mixture to evaporate spontaneously, and adding a small portion of metallic mercury if the quantity first employed should be completely dissolved. The crystals procured in this manner must be separated from the acid liquid and the mercury mixed with it. They are soluble in a small quantity of water, but much water decomposes the nitrate. A portion of binoxide of mercury is very apt to be formed during the preparation of this salt, and, according to some authors, a portion of subnitrate is produced, when it is attempted to saturate any excess of acid by a great excess of mercury. Mitscherlich affirms that the salt usually termed nitrate of mercury is a dinitrate.

1446. PERNITRATE OF MERCURY is obtained by heating metallic mercury in an excess of strong nitric acid, a large quantity of binoxide of nitrogen gas being disengaged ; crystals are deposited as the liquid cools. These crystals were considered to be composed of two equivalents of acid and one of binoxide, but, from some recent investigations, only one equivalent of acid appears to be combined with the binoxide. It has been found that the action which takes place between nitric acid and mercury is much more complicated than had been generally believed, and new combinations have been lately pointed out.

1447. In preparing nitrate of mercury for different purposes,

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great attention must be paid to the strength of the acid employ-
ed, the temperature to which the mixture is exposed, and the
relative proportions in which the acid and the metal are mixed
together, as all these circumstances have an important influence
upon the oxidation of the mercury and the nature of the resulting
salt.   If the acid be strong, and a larger quantity be employed
than is necessary to dissolve the mercury, and the solution be
assisted by heat, the mercury always attracts two equivalents
of oxygen, and binoxide of mercury is obtained in combination
with nitric acid ; but when the acid is diluted with three or four
parts of water, the solution allowed to go on at natural tempera-
tures, or assisted only by a very gentle heat, and more mercury
is used than the acid can dissolve, the oxide is obtained, which
unites with a smaller quantity of acid.

1448. BIPERSULPHATE OF MERCURY or Bisulphate of the
Binoxide, is prepared by boiling two parts of metallic mercury
to dryness with two and a half of sulphuric acid, exposing the
mixture to heat in a porcelain evaporating basin over a common
fire.   On the small scale, an ounce of mercury with the proper
quantity of acid may be boiled to dryness over a common fire
or good chauffer, taking care to avoid the fumes that are evolved,
not to boil the mixture violently, otherwise a quantity of the bi-
sulphate will be thrown out, and to remove it from the fire when-
ever it is dry.   It is obtained in the form of a white crystalline
powder when well prepared, perfectly dry, and not deliquescing
on exposure to the air.   The following diagram represents its
composition and the theory of its formation ; one portion of the
sulphuric acid affords oxygen to the mercury, and sulphurous
acid is disengaged, while the greater part of the acid unites with
the binoxide, the excess being dissipated along with the sulphu-
rous acid, and producing pungent suffocating fumes.   The water
that is combined with the common sulphuric acid is not repre-
sented, but it will be recollected that 49.1 of common sulphuric
acid, properly concentrated, contain 40.1 of dry acid and 9 of water.

Fig. 208.

Before Decomposition.			After Decomposition.
Sulphuric Acid,	Sulph. Acid	32.2	32.2 Sulphurous Acid.
	Oxygen ...	8.	
Sulphuric Acid,	Sulph. Acid	32.2	32.2 Sulphurous Acid.
	Oxygen ...	8.	
Sulphuric Acid,	....	40.1	
Sulphuric Acid,	....	40.1	
Mercury,	....	203	299.2 Bipersulph. of Mercury.
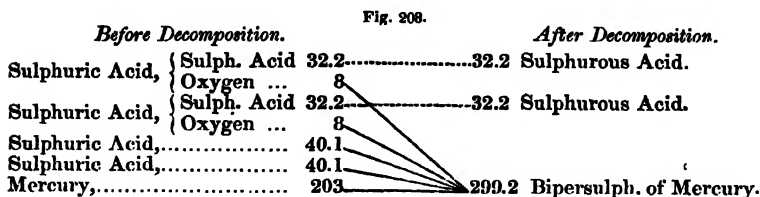
Four equivalents, accordingly, of sulphuric acid are required to convert one equivalent of mercury into bipersulphate, two of these affording oxygen to the metal, while the other two combine with the binoxide as it is formed. An excess of sulphuric acid is recommended, as a portion is always lost by evaporation; and should the operator find that a portion of metallic mercury remains in the salt procured, more sulphuric acid must be added, and the heat must be continued as before. This is an example of one of those numerous cases in which much more of one of the ingredients is used, than is either decomposed or brought into combination in the required product, not only to make up for any unavoidable loss, but also to present a larger surface as it were, that the action may proceed more speedily from the greater number of points of contact. The proportion of the ingredient in excess, it must be also remarked, is varied according to the composition of the product that may be required.

1449. Mix 299.2 grains of the bipersulphate of mercury with 203 of metallic mercury, and rub them intimately together in a mortar; the metallic mercury is supposed to divide the oxygen and acid in the bipersulphate with the 203 parts of mercury which it already contains, and 502.2 parts of SULPHATE OF MERCURY (Sulphate of the oxide) are obtained, the different materials arranging themselves in the manner represented in the annexed diagram.

Fig. 209.

Before Decomposition.		*After Decomposition.*
203 Mercury,...........................	203	251.1 Sulphate of Merc.
299.2 Bipersulphate of Mercury, ...	Oxygen...... 8. Sulph. Acid 40.1. Oxygen...... 8. Sulph. Acid 40.1. Mercury..... 203	251.1 Sulphate of Mercury.
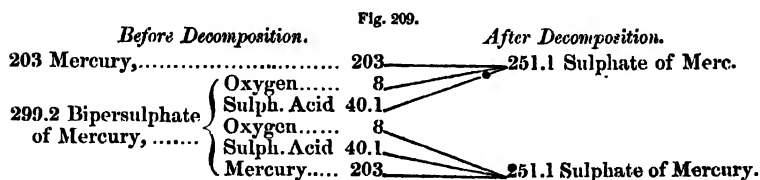
In this manner, the sulphate of mercury is procured more conveniently for the preparation of calomel, the purpose to which it is usually applied, than by the action of sulphuric acid heated gently with metallic mercury.

1450. Throw half an ounce or an ounce of the bipersulphate of mercury, heated to the temperature of 400° or 500°, into five or six pounds of boiling water, in a large glass-flask or earthen basin. A yellow-coloured precipitate is immediately thrown down,

which has been regarded as a compound of one equivalent of sulphuric acid and one of the binoxide of mercury, another portion of the binoxide remaining in solution with an excess of acid. The annexed diagram gives a precise view of the nature of the reaction, supposing the salt that remains in solution to contain only one more equivalent of acid than the bipersulphate. The yellow-coloured precipitate is usually termed SUBSULPHATE OF MERCURY, or TURPETH MINERAL.

Fig. 210.

Before Decomposition.			After Decomposition.
299.2 Biper-sulphate of Mercury	Sulphuric Acid 40.1		339.3 Terpersulph. of Merc.
	Sulphuric Acid 40.1		
	Binox. of Mer. 219		
299.2 Biper-sulphate of Mercury	Sulphuric Acid 40.1		
	Sulphuric Acid 40.1		
	Binox. of Mer. 219		259.1 Persulphate of Mercury.
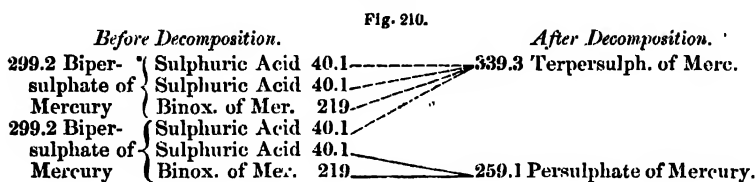
According to Phillips, Turpeth mineral consists of 3 eqs. of acid and 4 of binoxide of Mercury.

It should be washed repeatedly with water on a filter, and then set aside to dry.

1451. SULPHURET OF MERCURY (*Symb.* SHg. *Eq. by W.* 219.1 = S.16.1 + 203 Hg). This compound is precipitated of a blackish colour, when hydrosulphuric acid gas is passed through a solution of nitrate of mercury, or through water containing chloride of mercury suspended in fine powder.

1452. Prepare a portion of the BLACK SULPHURET of MERCURY by rubbing together equal weights of mercury and sulphur till the globules disappear. It is frequently called *Ethiops Mineral,* and is a mixture of sulphur and bisulphuret of mercury. (Brande.)

1453. BISULPHURET OF MERCURY or *Artificial Cinnabar* (*Symb.* S²Hg. *Eq. by W.* 235.2 = S.32.2 + 2.03 Hg). The common method of preparing this compound is by melting 40 parts of sulphur in an iron cup over a chauffer, and adding 200 of metallic mercury, stirring constantly with an iron rod till the mixture has assumed a uniform appearance, and taking care to apply only a moderate heat, to prevent it from taking fire ; the mixture is extremely apt to take fire when the heat is too great, and the iron cup must be covered when this takes place, removing the chauffer for a short time. It must afterwards be

reduced to powder, and sublimed in a close vessel. Eight parts more of sulphur are recommended to be taken than is absolutely necessary to convert the metallic mercury into bisulphuret, to make up for a portion of sulphur which is always lost. The sublimation should be conducted slowly. The bisulphuret condenses in a crystalline cake having a radiated appearance. A small quantity may be easily sublimed in a tube, conducting the operation in the manner described in 1403.

1454. When salts that contain binoxide of mercury are decomposed by an excess of hydrosulphuric acid, the precipitate that is obtained, when complete decomposition has been effected (see par. 1437), has a dark colour, and may be regarded as a compound of bisulphuret of mercury and water, as it presents the same appearance as the bisulphuret of mercury when dried and sublimed in the usual manner. According to this view, two equivalents of hydrosulphuric acid are required for every equivalent of binoxide decomposed, reacting on it probably in the manner presented in the following diagram.

Fig. 211.

Before Decomposition.　　　　　　　　　　　*After Decomposition.*

2 Eqs. of Hydrosulphuric Acid 34.2 ⎰ Hydrogen ...1————●—-9 Water.
⎱ Hydrogen .. 1————-9 Water.
⎰ Sulphur...16.1
⎱ Sulphur...16.1

1 Equivalent of Binoxide of Mercury, 219 ⎰ Oxygen... 8
⎱ Oxygen... 8
Mercury 203————235.2 Bisulphuret of Merc.
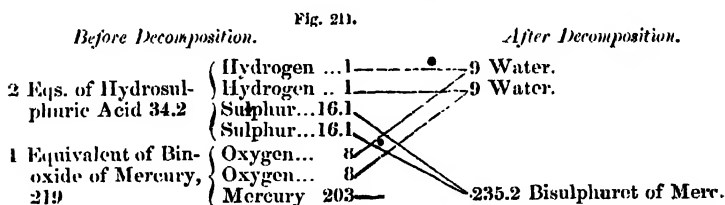
1455. Bisulphuret of mercury is sometimes adulterated with red lead or chalk, either of which may be easily detected by exposure to heat on thin pieces of iron or copper, the pure bisulphuret being volatilized, while the chalk or oxide of lead remains, the latter losing a portion of its oxygen and being converted into yellow oxide of lead. When the bisulphuret of mercury is reduced to a fine powder, it presents a very beautiful colour, and is well known in this form by the name of Vermilion. Chevallier pointed out, that, in Paris, sugar confectionary was frequently coloured with bisulphuret of mercury and other deleterious ingredients, a practice that has been stopped there, in consequence of a report from the Council of Health. Dr O'Shaughnessy has lately extended the investigation of this subject to our own country, and has shewn that the same means

are frequently resorted to in London for colouring confectionary, and has pointed out minutely the method of detecting the presence of the poisonous matters that are generally used.—*Lancet*, vol. ii. 1831–32.

1456. DIPERCARBONATE of MERCURY is formed when a solution of the carbonate of potassa is added to a solution of the pernitrate of mercury.

1457. Expose a small quantity of the precipitated dipercarbonate of mercury to heat in a tube over a spirit-lamp ; carbonic acid and oxygen gases are disengaged, and small globules of metallic mercury soon appear a little above the part of the tube that is held over the flame.

1458. ACETATE of MERCURY is easily prepared according to the process of the Edinburgh College.   Three parts of mercury are to be dissolved in four and a half of their diluted nitrous acid (composed of equal weights of water and the strong fuming acid obtained in the manner described in 191), and the solution must be added to an equal weight of the acetate of potassa dissolved in thirty-two times its weight of water ; nitrate of potassa remains in solution, and acetate of mercury is deposited in small crystals as the liquid cools.

Fig. 212.

Before Decomposition.			After Decomposition.
98.68 Acetate of { Potassa............... 47.2			101.4 Nitrate of Potas.
Potassa { Acetic Acid.........51.48			
265.2 Nitrate of { Nitric Acid......... 54.2			
Mercury { Oxide of Mercury...211			262.48 Acetate of Merc.

In preparing the nitrate, the usual precautions must be taken to prevent the formation of binoxide of mercury.

1459. A compound of BINOXIDE of MERCURY and ACETIC ACID may be procured by digesting the binoxide in acetic acid.

1460. FULMINATE of MERCURY, or *Fulminating Mercury*, as it is usually termed, is prepared by mixing with alcohol pernitrate of mercury dissolved in an excess of acid.   For this purpose, 100 grains of mercury may be digested with an ounce and a half by measure of strong nitric acid in a Florence flask till they are dissolved.   The solution, after it has been allowed to cool a little, is to be added in small quantities at a time to two ounces of alcohol in another flask ; exposing it afterwards to a very gentle heat over a lamp or chauffer, should this be

necessary, till white fumes begin to appear. If the action should proceed very violently, it must be moderated by adding a little alcohol ; and if it do not commence soon after the mixture is exposed to heat, a few drops of strong nitric acid, poured in by a pipette, will soon cause the white fumes to appear.   These fumes are extremely heavy, and may be poured from one vessel to another, or through a funnel ; their composition has not been minutely examined ; they contain a large quantity of nitric ether in vapour.

1461. Dr Ure has remarked, that there may be considerable latitude in the proportion of materials employed, Gay Lussac, Aubert, and Pellissier recommending 12 of nitric acid, and 12 of alcohol (by weight) to 1 of mercury, while Mr Howard, who discovered this compound, used the annexed proportions.

Mercury,									100
Nitric Acid, specific gravity 1.3, 1½ measured ounce,							.		884
Strong alcohol, 2 measured ounces,					.	.	.	.	750

Dr Ure prefers the following proportions,

Mercury,	.	.	.	.	.	.	.	.	100
Nitric Acid, 1.35,	.	.	.	.	.	.	.	.	950
Alcohol, 0.835,	.	.	.	.	.	.	.	.	850

These, he remarks, afford about 120 of a perfect fulminate, and the supernatant fluid does not retain more than 5 grains of mercury.—*Royal Instit. Journ.* i. 140.

1462. When the reaction has ceased, a quantity of a white crystalline powder is found to have been deposited, which is the fulminating mercury ; it must be washed on a filter with water, and allowed to dry by exposure to the open air.   It should never be put into a bottle with a ground stopple, as it detonates by friction and percussion, but should be merely folded in a piece of paper, and kept in a wide-mouthed phial with a cork fitting loosely to it.   The fulminic acid in this compound is formed by the decomposition of part of the nitric acid and the alcohol, the nitrogen being derived from the acid and the carbon from the alcohol.

1463. Place ten or twelve grains of fulminating mercury on a block of iron, and touch it with a red-hot wire ; it immediately detonates with a quick but not a sharp or loud report,

and a bluish-white flame, its elements being separated from one another. It may be detonated also by striking it with a hammer ; it is the basis of the detonating mixture employed for the anti-corrosive percussion caps.

1464. If two or three grains be put into a dry Florence flask, to which a brass cap and stopcock have been fitted, and exposed to heat over a spirit-lamp after the air has been exhausted as completely as possible, a flash of light will soon be perceived, but no report is heard, and metallic mercury is deposited on the inside of the flask. The utmost caution is required in performing this experiment, for, if the air of the apparatus be not exhausted, or the quantity of fulminate be too great, a loud explosion takes place, and the flask is blown to pieces.   Seven grains of fulminating mercury were found sufficient to produce this effect when the flask had been exhausted of air as completely as possible. Fulminate of mercury is employed in the preparation of detonating match powder.   100 grains of fulminate, 30 of water, and 60 of gunpowder, when well mixed together on marble with a wooden muller, afford a quantity of this powder sufficient to mount 400 detonating caps.

1465. CHLORIDE OF MERCURY or CALOMEL, formerly called *Submuriate* or *Mild Muriate of Mercury.* (*Symb.* Cl Hg. *Eq. by W.* 238.5 = Cl 35.5 + 203 Hg.) This important compound may be easily prepared from the bichloride of mercury, the sulphate of mercury, or the nitrate of mercury.

1466. When the bichloride is employed for this purpose, every equivalent (274) must be mixed with an equivalent of mercury, rubbing them together in a Wedgwood's mortar, and continuing till the metallic globules of the metal completely disappear, and the mixture is converted into an ash-grey-coloured powder.   It should be turned over from time to time with a spatula, when it appears to cake together at the bottom of the mortar, and great care must be taken to avoid the small particles of the bichloride that are carried up at first when it is reduced to powder, as they are extremely deleterious ; a few drops of water added to the mixture prevent these particles from being disengaged, and facilitate the action of the mercury on the bichloride.

1467. The grey-coloured mass must then be exposed to heat in a subliming apparatus.   When a few ounces of materials are

used, a retort with a short and wide neck will perhaps be the most convenient apparatus for the student, heating it over a chauffer, or by placing it in a sand-bath. The calomel condenses in the neck after it has been converted into vapour. The more proper apparatus for this sublimation is the alembic, a description of which is given under Miscellaneous Apparatus. On a smaller scale, the sublimation may be easily effected in a glass-tube, proceeding in the manner directed in 1403.

1468. The following diagram explains the theory of the action.

Fig. 213.

Before Decomposition.   *After Decomposition.*

274 Bichloride of { Mercury...203————238.5 Chloride of Mercury.
Mercury,   { Chlorine...35.5
          { Chlorine...35.5
203 Mercury.......................203————238.5 Chloride of Mercury.

$$Cl^2 Hg \ \& \ Hg = 2(Cl Hg).$$
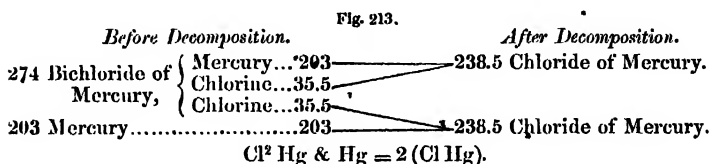
1469. A small quantity of the bichloride of mercury generally escapes during the decomposition, and a little metallic mercury also appears between the neck of the retort and the condensed calomel. By repeating the sublimation, it is usually obtained in a purer form, and any bichloride may be removed by reducing the cake to a fine powder and washing it with cold water, which dissolves the bichloride, but has no action on calomel. The London College directs a solution of the hydrochlorate of ammonia to be used for this purpose instead of water, the bichloride being much more soluble in it than in water. Mr Brande states, that a solution of common salt may be used instead of a solution of the hydrochlorate of ammonia, but mentions the important objection to the use of either of these substances which Mr Hennel pointed out, viz. that calomel is resolved into bichloride of mercury and metallic mercury, when boiled with a solution either of hydrochlorate of ammonia or of common salt.

1470. If calomel be suspected to contain bichloride of mercury, a small quantity should be worked in a Wedgwood mortar with distilled water for some minutes, and the liquid should then be filtered. If any bichloride of mercury be mixed with the calomel, it is dissolved, and, on adding lime-water in excess to the clear liquid, binoxide of mercury will be precipitated of a yellow colour.

1471. The next method of preparing chloride of mercury is from a mixture of the bipersulphate of mercury, metallic mercury, and common salt. Or, sulphate of mercury may be obtained, in the first place, by the mutual action of the bipersulphate and metallic mercury (see 1449), and then be intimately mixed and heated with common salt, and sublimed in the manner already described in 1467. Every 251.1 parts of the sulphate (one equivalent) require 59 parts of chloride of sodium (one equivalent), sulphate of soda remaining in the bottom of the retort, while chloride of mercury is sublimed as before. The diagram gives a more precise view of the nature of the reaction.

Fig. 214.

Before Decomposition.			*After Decomposition.*
251.1 Sulph. of Merc.	{ 211 Oxide of Mercury {	{ Mercury 203 —	238.5 Chloride of Merc.
		{ Oxygen 8	
	Sulphuric Acid......... 40.1		
59 Chloride of Sodium	{ Chlorine...... .... 35.5		
	{ Sodium............... ... 23.5		71.6 Sulphate of Soda.

$$\ddot{S}\cdot Hg \ \& \ Cl\,Na = Cl\,Hg \ \& \ \ddot{S}\cdot Na.$$

Or, if the bipersulphate, mercury, and common salt, be mingled together by one operation and then heated, the symbolic expression will be as follows :—

$$2\ddot{S} + \dot{H}g \ \& \ Hg \ \& \ 2\,(Cl\,Na) = 2(Cl\,Hg) \ \& \ 2\,(\ddot{S}\cdot Na).$$

This process is preferred to any of the others, and was originally adopted at Apothecaries' Hall (Brande). ·

1472. The last method of preparing chloride of mercury which we shall describe is by precipitation from the nitrate (nitrate of the oxide). For this purpose, a solution of the nitrate of mercury, prepared with the usual precautions (1447) must be added to a solution of chloride of sodium in 50 or 60 parts of water ; chloride of mercury is immediately precipitated, and nitrate of soda remains in solution. 59 parts of chloride of sodium are required for every 265.2 parts of dry nitrate of mercury, but a considerable excess of chloride is generally taken ; the quantity of chloride of sodium recommended to be dissolved in the water is equal in weight to the mercury employed in the preparation of the nitrate. The diagram represents the reaction that takes place between the nitrate of mercury and the chloride of sodium.

Fig. 215.

Before Decomposition.   *After Decomposition.*

59 Chloride ..{ Sodium.....................23.5 _ _ _ _ _ _ _ _85.7 Nitrate of Soda.
of Sodium   { Chlorine................ .35.5

265.2 Nitrate { Nitric Acid............54.2
of Mercury   { 211 Oxide of { Oxygen 8
             {   Mercury { Merc. 203 _____238.5 Chloride of Merc.

Symb. Cl Na & ∶∶N ·Hg = ∶∶N ·Na & Cl Hg.

The chloride is precipitated in the form of a white powder, and must be washed and filtered with pure water.

1473. The following diagram gives a view of the reaction that would take place between the mercurial salt and the chloride, supposing the whole of the mercury to be converted into bipernitrate (composed of two equivalents of nitric acid and one of the binoxide), and each equivalent of this substance to decompose two of common salt.

Fig. 216.

Before Decomposition.   *After Decomposition.*

                    { Mercury.........203 _ _ _ _ _ _ _ 274 Bichloride of Merc.
327.4 Bipernitrate { Oxygen 8
of Mercury   { Nitric Acid.....54.2
                    { Oxygen.......... 8
                    { Nitric Acid.....54.2

                      Chlorine.........35.5
118 Chloride of   Chlorine.........35.5
Sodium=59×2   Sodium...........23.5 _ _ _ _ _ _ 85.7 Nitrate of Soda.
                      Sodium...........23.5 _ _ _ _ _ _ 85.7 Nitrate of Soda.

1474. The student will now perceive the great importance of attending to the quantity of oxygen and acid combined with the metal, as, in the present instance, nothing would be obtained but bichloride of mercury and nitrate of soda, instead of chloride of mercury and nitrate of soda, if the mercury were converted into a bipernitrate instead of a nitrate of the protoxide ; and, moreover, no precipitate would take place, bichloride of mercury being soluble in water. He will likewise remark that though chloride of mercury is prepared from a mixture of chloride of sodium and sulphate of mercury, bichloride of mercury is formed when bipersulphate of mercury is used. (See Fig. 217, next page.)

1475. Chloride of mercury is decomposed by solutions of potassa, soda, and ammonia, hydrosulphuric acid, and of the hydrosulphates.

1476. BICHLORIDE OF MERCURY, or *Corrosive Sublimate*, for-

merly called *Muriate or Oxymuriate of Mercury* (*Symb.* Cl² Hg.
Eq. by W. 274 = Cl.71 + 203 Hg). The bichloride is usually
obtained by exposing a mixture of one equivalent of the biper-
sulphate of mercury (299.2) to heat along with two equivalents
(118) of chloride of sodium, and conducting the process in the
manner described for the preparation of calomel from the sul-
phate of the oxide.   The fumes and watery vapoury that are
disengaged are loaded with bichloride of mercury, and must be
carefully avoided, as they are extremely deleterious ; the sand-
bath should be placed under a chimney, or taken out into the
open air.   Many persons have been severely affected while pre-
paring the bichloride by themselves, from not attending to this
circumstance.

The following diagram shows the nature of the reaction that
takes place :

Fig. 217.

Before Decomposition.   *After Decomposition.*

299.2 Bipersulph. { Mercury... 203   274 Bichloride of Merc.
of Mercury   { Oxygen 8
                  { Sulphuric Acid 40.1
                  { Oxygen............ 8
                  { Sulphuric Acid 40.1

118 Chloride of   { Chlorine... ..... 35.5
Sodium = 59×2   { Chlorine......... 35.7
                  { Sodium..... ... . 23.5   71.6 Sulphate of Soda.
                  { Sodium... ... .. 23.5   71.6 Sulphate of Soda.
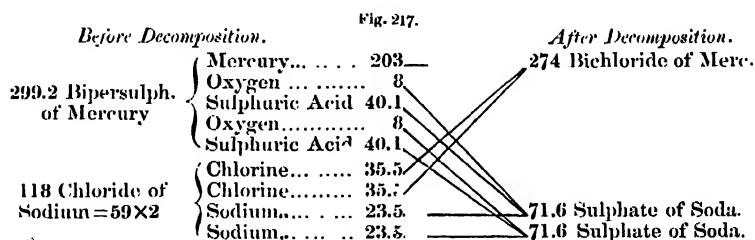
1477. The bichloride is sublimed, and condenses in a crystal-
line cake with a beautiful network of prismatic crystals, the sul-
phate of soda remaining at the bottom, as in the preparation of
calomel from the sulphate of the protoxide.   The heat should be
moderate, and not more than is required to volatilize the bichlo-
ride slowly, to prevent as much of it as possible from being car-
ried off in the form of vapour ; towards the end of the process,
the heat may be increased for a short time.

1478. Bichloride of mercury is soluble in nearly 20 parts of
water at 60°, and in about 3 parts of boiling water.   The solu-
tion may be regarded as a compound of water and bichloride of
mercury, or it may be supposed that a portion of water is de-
composed when the bichloride acts on this fluid, and that a bi-
perhydrochlorate of mercury is formed ; two equivalents of water
must then be decomposed by one equivalent of the bichloride,
in the manner represented in the following diagram.

Fig. 218.

Before Decomposition.		After Decomposition.

9 Water × 2 ...
⎧ Hydrogen...1 _____ 36.5 Hydrochloric Acid.
⎨ Hydrogen...1 _____ 36.5 Hydrochloric Acid.
⎪ Oxygen   8
⎩ Oxygen   8

274 Bichloride of Mercury
⎧ Chlorine 35.5
⎨ Chlorine 35·5
⎩ Mercury 203 _____ 219 Binoxide of Mercury.
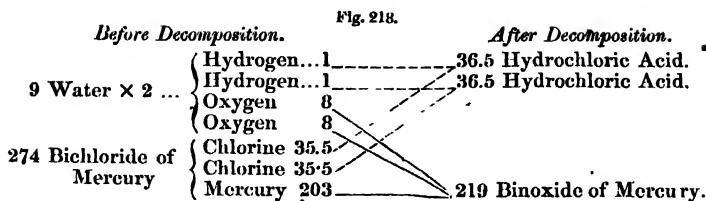
1479. Again, according to this view, when the solution of the biperhydrochlorate is evaporated to drynesss, the hydrochloric acid and binoxide of mercury are again resolved into water and bichloride of mercury. ' The following diagram completes the view of these complicated reactions :

Fig. 219.

Before Decomposition.		After Decomposition.

2 equivalents of Hydrochloric Acid 36.5 = 73
⎧ Hydrogen...1 _____ 9 Water.
⎨ Hydrogen...1 _____ 9 Water.
⎪ Chlorine 35.5
⎩ Chlorine 35.5

1 equivalent Binoxide of Mercury = 219
⎧ Oxygen ... 8.
⎨ Oxygen ... 8.
⎩ Mercury...203 _____ 274 Bichloride of Mercury.
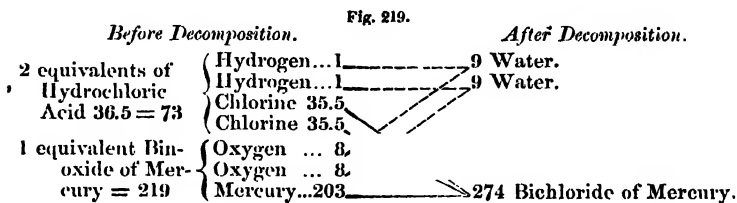
1480. Bichloride of mercury has its solubility in water much increased by the addition of hydrochlorate of ammonia or common salt (see 1469).   It is also soluble in alcohol and in sulphuric ether.   Its taste is acrid, metallic, astringent, and very disagreeable.   Pure bichloride of mercury is completely volatilized by heat, and is easily distinguished from calomel by its solubility in water, and the yellow precipitate which it gives with lime water.

1481. A compound of hydrochloric acid and binoxide of mercury, black and crystalline, has lately been described by Mr Phillips.   It consists of two equivalents of hydrochloric acid, 73, and one of binoxide, 219 ; it has accordingly been termed Biperhydrochlorate of Mercury.

1482. The student should now make a number of experiments with a solution of the bichloride of mercury and solutions of the alkalis, alkaline earths, hydrosulphuric acid water, solutions of the hydrosulphates, of chromate of potassa, acetate of lead, and several astringent vegetable solutions—by all of which it is decomposed.

1483. The HYDRARGYRI AMMONIO-CHLORIDUM (formerly called the MURIATE OF AMMONIA AND MERCURY, or the *Hydrargyrum Præcipitatum Album* of the London College, and the *Sal Alembroth* of the older chemists), may be prepared by adding a solution of carbonate of potassa to a solution of the bichloride of mercury in hydrochlorate of ammonia, as long as any precipitation takes place. The following are the proportions recommended ; four ounces of the hydrochlorate of ammonia are to be dissolved in four or five pints of distilled water, and six ounces of the bichloride of mercury must then be dissolved in this solution, separating by filtration the white precipitate that is thrown down on adding the solution of carbonate of potassa, and washing it with water on the filter. According to the process introduced into the last edition of the London Pharmacopœia, this compound is now formed at once by the addition of a solution of ammonia to a solution of the bichloride of mercury.

1484. The precise composition of this compound is still involved in considerable obscurity. During its preparation, according to Dr Kane, half of the chlorine is withdrawn by part of the ammonia, while the whole of the mercury is precipitated in the form of a new compound of binamide and bichloride of mercury. But according to others, it should be regarded as a compound of hydrochlorate of ammonia and binoxide of mercury, or as a compound of ammonia with the bichloride and binoxide of mercury (Phillips).

1485. IODIDE OF MERCURY may be obtained by adding a solution of the iodide of potassium to a solution of the nitrate of mercury (protonitrate) ; it is immediately precipitated in the form of a yellow powder ; the potassium combines with the nitric acid and oxygen, of the nitrate, the iodine and mercury forming iodide of mercury.

Symb. $IK \,\&\, \ddot{:}N \cdot Hg = IHg \,\&\, \ddot{:}N \cdot K$.
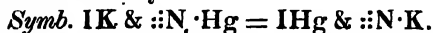
1486. BINIODIDE or PERIODIDE OF MERCURY is formed and precipitated of a red colour, when a solution of bipernitrate of mercury is added to a solution of iodide of potassium, two equivalents of the latter being decomposed by one of the bipernitrate, and the usual reaction taking place between the acid and binoxide.

Symb. $2 \, IK \,\&\, 2\ddot{:}N + \ddot{:}Hg = I^2Hg \,\&\, 2 \, (\ddot{:}N + \cdot K.)$
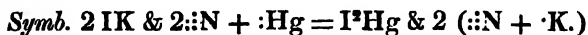
1487. It may also be obtained very easily by heating two eqs.

of iodine with one of mercury in a glass-tube; a brisk ebullition takes place, and biniodide of mercury is sublimed, condensing on the sides of the tube, and assuming a very rich crimson colour as it cools.

1488. The iodide and biniodide of mercury have both been frequently formed of late by merely triturating iodine and mercury in the required proportions, after adding a little alcohol.

1489. Other compounds of mercury and iodine have been described, more particularly the SESQUINIODIDE OF MERCURY, which is formed when solutions of iodide of potassium and of the nitrate and bipernitrate of mercury are mingled—the IODURETED BICHLORIDE OF MERCURY, produced by adding a solution of the bichloride to an alcoholic solution of iodine till the colour disappears—and a compound formed by dissolving the biniodide of mercury in a solution of the bichloride, which appears to consist of both these salts.

1490. Compounds of bromine and mercury may be made in the same manner as those of iodine and mercury.

CHAP. II.—SILVER.

Symb. Ag. *Eq. by W.* 108.3. *'Sp. gr.* 10.5. *A strong red-heat* (1873° Daniell) *is required to fuse it; and by a very high temperature it may be dissipated in vapour.*

1491. THE silver of commerce is procured principally from ores of native silver, of sulphuret of silver, or from ores of lead containing portions of this metal, from which it is extracted by the oxidation of metallic lead, as in the process of cupellation.

1492. Ores of native silver, mixed with much stony matter, are reduced to powder on the large scale by machinery, and agitated with mercury and water in a barrel. The mercury combines with the silver and forms an amalgam, which is separated from the stony matter, and the mercury is then removed by distillation, the silver being left.

1493. To obtain silver from the sulphuret of silver, a more complicated process is necessary. It is heated in a reverberatory furnace with common salt, by which chloride of silver is

obtained, and, when this is agitated in barrels with mercury, water, and fragments of iron, the iron removes the chlorine and is dissolved in the water, while the mercury combines with the silver, forming an amalgam, from which the mercury is to be separated by distillation. This is the general nature of the action that takes place, but it has not been so minutely examined as is desirable : the presence of a little sulphuric acid, or of some metallic salt containing it, appears to be of importance.

1494. In extracting silver from ores of lead, a very great improvement has lately been introduced by Mr Pattinson. Instead of separating all the lead by cupellation, he removes a large portion of the lead in the first instance by crystallization after melting it, having found that it separates with facility, on reducing the temperature cautiously, from the more fusible compound of lead and silver which is left in the liquid form. This separation of metallic lead is continued till the alloy that is left is many times richer in silver than the lead originally procured from the ore. There is accordingly much less lead to oxidate in separating it finally from the silver by heat and air (see Lead). and at the same time all the expense previously incurred in oxidating the whole of the lead, and then reducing it to the metallic form is greatly diminished. Many lead-ores in which the quantity of silver was too small to admit of its being extracted economically by the former process, are now used with advantage for the separation of silver since the introduction of Mr Pattinson's process.

1495. Silver being frequently alloyed with a small quantity of copper, it is of importance to know the processes by which they may be separated. The one usually followed consists in exposing the alloy to the action of the air at a high temperature along with several times its weight of lead, the copper and the lead being oxidated and fused, while metallic silver remains. For this purpose, the alloy must be placed on a cupel, and exposed to heat in the muffle of the cupellation furnace : when the student has not the advantage of a cupellation furnace, the cupel may be placed in the open fire in the manner described in 1068, page 307.

1496. The quantity of lead required depends on the richness of the alloy ; if it contain about a tenth part of copper, which is usually the case, six or seven times its weight of lead will be

found quite sufficient ; but if more copper be present, it will be necessary to use a larger quantity of lead.

1497. The use of the lead in this process is to form a fusible compound with the copper during the oxidation of both metals, which is speedily absorbed by the bone-ashes, while the pure silver remains above. If too small a quantity of lead be employed, a brown crust gathers on its surface which is not fused, and prevents the oxidation of the remainder of the lead and copper. The usual precautions must be taken in bringing the muffle to a proper temperature, and the process is known to be completed by the *fulguration* or *brightening* as it is termed, which is seen when the last portions of lead and copper are oxidated and removed.

1498. On taking out the cupel, the silver is seen in the form of a metallic globule of a rich white colour and great lustre. The fused oxides give the cupel a very dark appearance where they have been absorbed, deeper in proportion to the quantity of copper which the alloy may have contained. The appearance which it presents should be compared by the beginner with the result of the process described in 1067, where pure lead is directed to be exposed to heat on a cupel till it is oxidated.

The experiment may be made with a few grains of the alloy, or a much larger quantity may be employed.

1499. Other processes for separating silver from copper are frequently resorted to. Digest the alloy with one and a half times its weight of nitric acid diluted with twice its bulk of water in a glass-flask or evaporating basin till it is dissolved, and pour the liquid into hydrochloric acid diluted with eight or ten times its bulk of water, using a quantity of the strong acid equal in weight to the alloy employed. Chloride of silver is precipitated.

A slight excess of nitric acid favours the precipitation of the chloride. The solution prepared in the manner directed is always acid ; should a solution be employed containing no excess of nitric acid, it ought to be acidulated with this acid before adding the hydrochloric acid. The diagram represents the action that takes place between the hydrochloric acid and the nitrate of silver.

Fig. 220.

Before Decomposition.		*Products.*

170.5 Nitrate of Silver, { Nitric Acid......54.2 ---------------- 54.2 Nitric Acid.
116.3 { Oxygen 8 ---------,9 Water.
Oxide { Silver 108.3

36.5 Hydrochlo-ric Acid, { Hydrogen......... 1
Chlorine......... 35.5 ---------143.8 Chloride of Silver.

The copper is retained in solution in the form of nitrate or hydrochlorate of copper with the excess of nitric acid. When the chloride of silver has subsided, the clear liquid should be decanted, and water acidulated with a little nitric acid should be poured upon the precipitate. This must also be decanted when the precipitate shall have again subsided, and by repeating this, all the copper is removed.

The chloride of silver may then be washed with as little water as possible in a plate or evaporating basin, and dried before the fire.

1500. To procure the metallic silver from the chloride, different processes are followed. It may be obtained easily in the following manner :—Take 50 parts of carbonate of potassa and 40 of dry carbonate of soda, fuse them in a common Hessian crucible, and shake the liquid in the crucible, so that the interior surface shall be coated with the mixed carbonates. Throw out the excess of the mixed carbonates, and then put into the crucible, after allowing it to cool a little, 100 parts of the chloride, perfectly dry, and intimately mixed with 50 of the carbonate of potassa and 40 of dry carbonate of soda. On heating the mixture in a furnace, the chlorine is withdrawn by the bases of the alkaline carbonates, and the metallic silver is obtained in the form of a button below the fused saline matter. 100 grains of the chloride, with the proportion of alkaline carbonates mentioned, may be fused in a crucible capable of containing two fluid ounces. The excess of alkaline matter employed is of no importance on the small scale, and allows the particles of silver to collect together more easily.

1501. In this process, the mixed carbonates are preferred to either separately, as they are more fusible ; and it is of importance to line the interior of the Hessian crucible with the mixture, as the chloride of silver is very penetrating, and a portion is apt to pass through it, when this precaution is not adopted.

The crucible must be exposed to a bright heat in order to melt the silver.

1502. Were the decomposition effected by potassa alone, the annexed diagram would represent the action that takes place.

Fig. 221

Before Decomposition.			Products.
47.2 Potassa...............	{ Oxygen ...8		8 Oxygen.
	{ Potassium 39.2		
143.8 Chloride of Silver	{ Chlorine 35.5		74.7 Chlor. of Potass.
	{ Silver 108.3		108.3 Silver.

In the present instance, every portion of potassa or soda that reacts on the compound of silver and chlorine, loses the carbonic acid that was combined with it ; the chlorine, taking the metallic base, forms a chloride of potassium or sodium, and the metallic silver is disengaged. The excess of alkali employed is not decomposed.

1503. Another method of procuring the silver from the chloride consists in boiling it in water with metallic zinc, to which a little acid has been added. It is procured in this manner in the form of an ash-coloured powder, which may be melted into a globule by heating it in a crucible, adding a small quantity of carbonate of potassa or soda, or of the mixed carbonates. The zinc combines with the chlorine of the chloride, and remains in solution. Thin plates of zinc are preferred, and are boiled for several hours with the chloride ; 32.3 of zinc are required for 143.8 of the chloride of silver, but it is better to use an excess of zinc. The silver should be well washed and dried before it is fused.

1504. To prepare metallic silver from the chloride, Dr Ure recommends 100 parts of it to be fused in a crucible with 19.8 of pure lime and 4.2 of charcoal.

1505. Mr Keir discovered that, an acid liquor composed of eight parts of sulphuric acid and one of nitre has the property of dissolving silver, but that it does not act upon copper, and has accordingly recommended it to be employed for removing silver from plated goods. The action of the liquid is to be assisted by a moderate heat, not exceeding that of boiling water, and the silver should be precipitated by a solution of common salt, reducing the chloride that is thus obtained in the usual manner.

1506. Silver is often precipitated from its solution in nitric acid by a plate of copper ; nitrate of copper remains in solution.

1507. Silver may also be precipitated in the metallic form by mercury. The silver that is obtained in this manner should be exposed to heat in a crucible till it is melted, that the mercury which is mixed with it may be expelled. This process is seldom resorted to, however, except for the purpose of shewing the arborescent form in which the silver is separated by the mercury. It is in this manner that the *Arbor Dianæ*, as it has been termed, is usually prepared ; 50 grains of the fused nitrate of silver, dissolved in two or two and a half ounces of water, and put into a small glass with 100 grains of mercury, do very well for this purpose. The crystals of silver are deposited above the mercury and rise in the liquid, part of the mercury being slowly dissolved, as it combines with the oxygen and acid previously in combination with the silver.

1508. Silver is a white metal, with a very brilliant metallic lustre. It is exceedingly malleable and ductile, and is also possessed of considerable tenacity. It is scarcely tarnished, and does not oxidate, when exposed to air and moisture. It is readily oxidated and dissolved by the nitric acid, and by sulphuric acid when heat is applied. When long exposed to air, especially in much frequented places, silver is tarnished by the formation of a thin film of sulphuret of silver on its surface.

1509. OXIDE OF SILVER (*Symb.* OAg, or ·Ag. *Eq.* 116.3 = 0.8 + 108.3 Ag) may be obtained by adding a solution of the nitrate of silver to a solution of baryta, the oxide being immediately precipitated, while nitrate of baryta remains in solution. Solutions of the alkalis and other alkaline earths also precipitate oxide of silver from the nitrate. Other oxides of silver have been described, but they are of less importance.

1510. At a high temperature silver acquires a portion of oxygen from the air, but parts with it as it cools. By exposure for a very long time to an intense heat, the oxide that is formed is fused.

1511. FULMINATING SILVER is a compound of ammonia and oxide of silver, which is usually prepared by pouring water of ammonia on oxide of silver precipitated from the nitrate by lime-water, after washing it on a filter. In twelve hours the liquid

must be cautiously decanted, and the black fulminating compound that remains should be allowed to dry spontaneously on small pieces of filtering paper.

1512. As many accidents have occurred during the preparation of this compound, even with those who have been accustomed to chemical manipulation, it will be better for the beginner to pass over this process. It detonates with extreme violence when touched by any hard body. Even the touch of a feather has been found sufficient to produce a loud explosion. The liquid, also, when gently heated, affords a still more dangerous compound, which explodes even when touched under the surface of the liquid.

1513. The most delicate test of silver in solution is hydrochloric acid, or a solution of any hydrochlorate, chloride of silver being immediately precipitated in the form of a white curdy precipitate, which becomes of a purplish colour on exposure to light. Hydrosulphuric acid and solutions of the hydrosulphates give a black precipitate of sulphuret of silver ; arsenite of potassa gives a yellow precipitate of arsenite of silver ; with arseniate of potassa, the precipitate is of a brick-red colour ; chromate of potassa gives a similar tint, but of a more beautiful and deeper hue. Small metallic globules of silver, obtained by decomposing any of its compounds on charcoal before the blowpipe, are easily recognised by their brilliant white colour, their hardness, and the manner in which they rest above the surface of the charcoal, not being imbedded in it like many other metals reduced on charcoal, but rising above it, and adhering only by a small point. A plate of copper introduced into a solution of silver precipitates metallic silver.

1514. The most important salt of this metal is the NITRATE OF SILVER. It is prepared by digesting silver in a glass vessel with one and a half times its weight of nitric acid diluted with an equal bulk of water, and evaporating the solution to dryness. One portion of the acid affords oxygen to the silver, and binoxide of nitrogen is disengaged, the oxide formed in this manner combining with the acid that is not decomposed. When dissolved in less than its weight of hot water, the solution affords tabular crystals as it cools.

1515. The fused nitrate of silver of the different Colleges, or *Lunar Caustic*, is prepared by melting the crystallized nitrate

in a porcelain crucible, capable of containing four or five times as much as is employed, heating it very gently at first to prevent it from boiling over or being decomposed, and pouring it whenever it becomes quite liquid into cylindrical moulds. The operator must take care to avoid the very caustic sparks that are occasionally thrown out of the crucible during the fusion of the nitrate.

1516. Nitrate of silver is soluble in its own weight of water, stains the skin black, and is decomposed by sulphuric and hydrochloric acids, solutions of the alkalis and earths, hydrosulphuric acid; hydrosulphates, by many of the metals, and a great number of astringent vegetable solutions. It darkens on exposure to light, if it be exposed to dust or to any vegetable or animal matter, but when sealed hermetically in a glass-tube, so as to exclude all foreign matters, it is not affected by light.

1517. Common *marking-ink* is composed of a solution of this salt thickened with a little mucilage ; and the preparatory liquid, with which the part to be marked is previously moistened, is a solution of carbonate of soda also thickened with a little mucilage. 100 grains of the fused nitrate may be dissolved for this purpose in distilled water, and two or three drachms of mucilage added to the solution, keeping it in a bottle ; for the preparatory liquid, again, half an ounce of the carbonate of soda may be dissolved in two or three ounces of water, adding half an ounce of mucilage to the solution.

1518. SULPHATE OF SILVER may be obtained by digesting metallic silver in sulphuric acid, one portion of the acid being decomposed, and affording oxygen to the metallic silver while sulphurous acid is disengaged, and another combining with the oxide. It may be prepared also by adding a solution of the sulphate of soda to a solution of the nitrate of silver, nitrate of soda remaining in solution, and sulphate of silver being precipitated ; this is the more convenient method of preparing the sulphate. It requires a large quantity of water for its solution.

1519. Silver tarnishes rapidly when exposed to the action of sulphur or sulphureous compounds, a SULPHURET OF SILVER being formed. This compound is produced much more rapidly by the action of hydrosulphuric acid or hydrosulphate of ammonia upon salts of silver.

1520. PHOSPHATE OF SILVER is precipitated when a solution

of the phosphate of soda is added to a solution of the nitrate of silver, a double decomposition taking place, and nitrate of soda remaining in solution.

1521. CARBONATE OF SILVER may be obtained by adding a solution of an alkaline carbonate to a solution of the nitrate of silver.

1522. FULMINATE OF SILVER, another detonating compound of silver, less dangerous than the one already described, may be prepared by dissolving metallic silver in strong nitric acid, and adding the solution to alcohol, proceeding in the manner directed for the preparation of fulminate of mercury, and using the same proportions of metal, acid, and alcohol. It explodes much more violently than fulminate of mercury, and should be handled with still more precaution, never touching it with any thing but a piece of paper or a card, except for the purpose of experiment. It is detonated by heat, friction, percussion, and strong aqueous sulphuric acid, producing a very sharp report. A quarter of a grain is quite sufficient for each experiment. By rubbing it with a little sand, it instantly explodes. To detonate it with the acid, a small portion of acid is lifted out of the phial containing it by touching it with an iron-rod, shaking off previously any superfluous acid which might otherwise be thrown upon the operator by the force of the explosion.

1523. CHLORIDE OF SILVER is always formed when hydrochloric acid or a solution of any hydrochlorate is added to a solution of a salt of silver, being precipitated in the form of a white curdy looking powder. Exposed to the direct rays of the sun, it soon becomes of a purplish colour. This was formerly attributed to the separation of chlorine from a part of the chloride, but, of late, it has been affirmed that it arises solely from a change in the arrangement of the particles. Mr Weslar, again, states that the silver is in the form of a subchloride. It is easily fused by a temperature of about 500^8, forming a mass like a piece of horn as it cools, and hence it is often called *Luna Cornea* or *Horn Silver*. By a high temperature it is volatilized. When melted in a common Hessian crucible, it penetrates through its pores, and much is lost when heated considerably. It occurs native. Chloride of silver is formed in numerous chemical operations, and may be decomposed in the manner described in 1500. It is very soluble in a solution of ammonia.

1524. Iodide of Silver, of a greenish-yellow colour, is precipitated when iodide of potassium is added in solution to the nitrate of silver, nitrate of potassa being formed at the same time and left in solution.

CHAP. III.—GOLD.

Symb. Au. *Eq. by W.* 200. *Sp. gr.* 19.3. *Melts at* 2016 (Daniell).

1525. Gold is not found in the state of an earthy ore. It occurs pure, or combined with other metals. When gold is alloyed with copper, it may be separated by the process of cupellation, proceeding in the manner that has been described for the cupellation of silver; 15 or 20 grains of an alloy containing about a tenth of its weight of copper will be sufficient to shew the nature of the process on the small scale.

1526. Silver and platinum cannot be removed in this manner, as neither of these metals is oxidated by exposure to a high temperature. Platinum is not often found alloyed with gold, and silver may be separated by the operations of *Quartation* and *Parting.* Quartation consists in fusing the alloy with three times its weight of silver, by which the particles of the gold are separated to a greater distance from each other, and prevented from covering or protecting any of the particles of silver from the action of nitric acid. Parting, again, consists in boiling the alloy in seven or eight times its weight of nitric acid to remove the silver, diluting the acid with an equal weight of water or rather more, and repeating the operation with a smaller quantity of acid till the whole of the silver has been extracted. Gold not being soluble in nitric acid, all that the alloy may have contained is left in a porous mass of the same form as the original alloy, or reduced to powder. On the large scale, before the alloy is boiled in the nitric acid it is usually flattened, by drawing it out between rollers; on the small scale it is hammered on an anvil; whatever mode be adopted, it is always necessary to heat it and allow it to cool slowly before subjecting it to the action of the nitric acid.

1527. When gold is exposed to an intense heat by the oxy-hydrogen blowpipe, it is dissipated in vapour, and a purple powder may be collected, which has been regarded as an oxide of gold. Its composition is still uncertain.

1528. Oxide of Gold (protoxide) is prepared by decomposing the chloride of gold (protochloride) by a solution of potassa. It has a dark green colour.

1529. Peroxide or Teroxide of Gold, frequently termed Auric Acid, may be obtained by adding a solution of pure potassa to a solution of the terchloride of gold, taking care not to add excess of alkali; hydrochlorate of potassa remains in solution, and the teroxide is precipitated in combination with a portion of water, the usual reaction taking place between the metallic chloride and part of the water that is decomposed. As it is often associated with a portion of potassa, it has been recommended to redissolve it in nitric acid, sp. gr. 1.4, and to precipitate it again by the addition of water, which separates it from the nitric acid. By a temperature of about 212° the water is expelled, and the anhydrous teroxide remains.

1530. Terchloride of Gold, usually termed Chloride of Gold, may be obtained by digesting small fragments of gold in a mixture of one part of nitric acid and two of hydrochloric acid, evaporating the solution to dryness by a very gentle heat to expel any excess of acid. The gold is dissolved by the chlorine evolved by the mutual reaction of the nitric and hydrochloric acids. If the heat be too strong, the chlorine is partly or entirely dissipated, and nothing remains but the chloride or metallic gold; great caution is therefore required in evaporating the liquid to dryness.

1531. A weak solution of gold may be obtained by shaking gold-leaf with a solution of chlorine in water. The acids which act upon gold are the nitro-muriatic, and a mixture of chromic and hydrochloric acids; and in both cases chlorine may be considered the actual solvent, part of the oxygen of the nitric or chromic acid combining with the hydrogen of a portion of hydrochloric acid, and disengaging this element. Nitro-hydrobromic acid also, prepared from nitric and hydrobromic acids, can dissolve gold; and here the bromine is considered the proper solvent, being disengaged from the hydrobromic acid by the oxygen of the nitric acid combining with its hydrogen. Fluorine

also acts upon gold in the same manner as chlorine and bromine. Nitric, hydrochloric, sulphuric, and other acids, when perfectly pure and added separately, have no action upon gold.

1532. Digest the dry terchloride of gold in water, and filter the liquid : a solution of terchloride of gold is obtained of a deep reddish-brown colour.

1533. DINAURATE OF AMMONIA ·or AMMONIURET OF GOLD, called also FULMINATING GOLD, may be obtained by adding ammonia to a solution of the terchloride of gold as long as any precipitate appears, and digesting the precipitate in ammonia. It should be allowed to dry on a filter at natural temperatures after washing it with water. It is of a yellowish colour. It detonates violently by friction and percussion, or when exposed to heat, its elements being separated from one another ; and must never be touched with any hard substance except for the purpose of experiments. It should be kept in a wide-mouthed bottle, closed tightly with a cork, and in small packets of paper. According to Dumas, it contains gold, oxygen, chlorine, hydrogen, and nitrogen. It has been regarded, as its name indicates, as a compound of one eq. of auric acid and two of ammonia.   •

1534. Add a solution of the green sulphate of iron (protosulphate) to a solution of the terchloride of gold ; metallic gold is precipitated, and water is supposed to be decomposed, its hydrogen combining with the chlorine, while the oxygen converts the protoxide of iron into peroxide. Other explanations, however, have been given of the theory of the action, according to which the products in solution are regarded as sesquisulphate of iron and perchloride of iron. Many metals, sulphurous and phosphorous acids, hydrogen gas, phosphureted hydrogen, carbon, and other deoxidating agents, decompose solutions of gold, and precipitate it in the metallic form.

1535. Digest the precipitate thrown down by sulphate of iron in diluted sulphuric or hydrochloric acid, to remove any oxide of iron that may have been thrown down along with the gold, and the latter will be obtained in a state of great purity.

1536. Add a solution of the chloride of tin (protomuriate) to a solution of the terchloride of gold ; a purple precipitate is immediately thrown down, which has been regarded as a compound of binoxide of tin and the oxide of gold, or metallic gold. Se-

veral difficulties have been presented in determining its precise atomic constitution. It usually contains combined water, and its solubility in ammonia does not accord with the view that it is a mechanical mixture of gold and hydrated binoxide of tin It is well known by the name of *Purple of Cassius*, and is used for communicating a rich red or pink colour to glass. According to M. Buisson, the solution of tin employed ought to contain both protochloride and bichloride of tin ; he has given a precise formula for its preparation. See Journal de Pharmacie for October 1830, or Philosoph. Magazine and Annals, vol. viii.

1537. Touch a piece of crystallized borax with a glass-rod that has been dipped in a solution of the terchloride of gold ; on exposing it to heat before the blowpipe on a piece of earthenware or baked clay, or fusing it in a crucible, a glass will be obtained which will have a very rich red or pink colour. If a very strong degree of heat be applied and continued for a considerable time, the pink tint disappears, and metallic gold is then seen.

1538. *Ethereal Solution of Gold*, which is used for gilding a number of substances, may be easily prepared by shaking a strong solution of the terchloride with an equal bulk of pure ether, the ethereal solution collecting above, and a heavier liquid remaining below. It should be decanted immediately, and kept in a stoppered bottle enclosed in a case to protect it from the action of the light.

1539. CHLORIDE OF GOLD (protochloride) is prepared by exposing the terchloride carefully to a moderate heat, when two-thirds of its chlorine are expelled. The temperature to which it is subjected should be considerably below a red-heat, otherwise all the chlorine would be expelled.

1540. Gold and chlorine can combine with a number of metals, forming a series of triple compounds. Mr Johnston has published a memoir on several of the combinations of gold in the third volume of Dr Brewster's Journal, New Series.

CHAP. IV.—PLATINUM.

. Symb. Pt ; *Eq. by W.* 98.84.   *Specific gravity* 21.5.

1541. The process for preparing pure and malleable plati-
num has been minutely described by Dr Wollaston in the first
part of the Philosophical Transactions for 1829, to which I
must refer for a number of details, and particularly for a de-
scription of the press required in rendering the platinum mal-
leable, after it has been purified from the other metals with
which it is usually associated.   Though the beginner may not
probably attempt to render the platinum malleable, he will find
no difficulty in preparing it in a pure form, though in a minute
state of division.

1542. The hydrochloric acid employed for the aqua regia
used, is to be prepared by mixing equal measures of strong hy-
drochloric acid and water, and the nitric acid also should be
diluted ; aquafortis, termed also single aquafortis, is what Dr
Wollaston recommends.   For 120 parts of crude platinum, as
much of the hydrochloric acid as can dissolve 150 parts of mar-
ble, and as much of the nitric acid as can dissolve 40 parts of
marble, are employed.   The platinum is digested for three or
four days in the acid liquid with a heat gradually increased, the
solution is then decanted, and allowed to stand till a quantity
of a fine powder containing iridium has subsided.   It may then
be mixed with a solution of 41 parts of hydrochlorate of ammo-
nia in 205 parts of water.   The yellow precipitate that is thrown
down must be well washed and ultimately pressed, to remove
adhering impurities.   On exposing it to heat, metallic platinum
is left, hydrochlorate of ammonia and chlorine being expelled.

1543. The liquor that remains after the precipitation of the
solution by the hydrochlorate of ammonia retains 11 per cent.
of platinum.   It may be recovered by precipitation along with
some of the other metals in solution, by immersing clean bars of
iron in the liquid, dissolving the precipitate in a proportionate
quantity of aqua regia, similar to that described in 1542.   In this
case, however, before precipitating by a solution of hydrochlo-
rate of ammonia, every 32 parts by measure of the nitro-muri-

atic liquid must be mixed with one by measure of strong hydrochloric acid, to prevent the precipitation of any lead or palladium.

1544. Platinum is not fused in general on exposing it to the strongest heat of a smith's forge ; small portions may be easily melted, however, by drawing it into thin wires, and holding it in the flame of the oxyhydrogen blow-pipe, and Mr Maughan has lately fused in this manner considerable quantities, as one or two ounces. It must not be considered as infusible in all kinds of furnaces, several cases having lately been met with in which it was melted in furnaces charged with coke or anthracite coal. It may be welded and hammered into various forms, like iron, by exposing it to a high temperature, and it is in this manner that crucibles and other vessels made of this substance are formed.

1545. In experimenting with apparatus made of platinum, it should never be allowed to come in contact with lead, antimony, or tin, when heated, as these metals combine with it, and form a very fusible compound. Neither should it be heated in a coal or cinder fire, where slag or ashes from the coal may fix upon it, as these are in general removed with difficulty, and prevent the platinum apparatus from being so freely used. Berzelius's spirit-lamp, or the spirit-lamp introduced by Mr Arthur Trevelyan, are best adapted for heating the platinum-crucible, and when these are not used, charcoal alone should be employed.

1546. By dissolving platinum, and precipitating it in the same manner as the ore, the ammonio-chloride of platinum is easily procured in the form of a yellow powder, and on heating it in a small crucible protected by a cover, it becomes of a grey colour, and forms the *spongy platinum*, which becomes incandescent with hydrogen gas in the manner described in 83, &c. Different kinds of lamps have been constructed, in which the spongy platinum is employed to produce an instantaneous light by directing a stream of hydrogen gas upon it ; one has been shewn in page 27, Fig. 45. The annexed figure represents another ; *a* the external glass-jar, containing the diluted sulphuric acid ; *b* the interior suspended jar, open below, and in which the hydrogen is accumulated by the action of the diluted acid upon the zinc *c*. The small aperture *d* allows air to escape from the outer glass vessel as the hydrogen is formed within *b*, and forces the acid liquid to rise in *a*. The platinum ball *f* is protected,

when not in use, by a cap, which is represented by the dotted line, over it; but when the apparatus is in use, the mere raising of this cap, so as to make it assume the position seen in *e*, opens the stopcock at the same time, and the hydrogen is then propelled, as represented in the figure, upon the platinum.

Fig. 222.
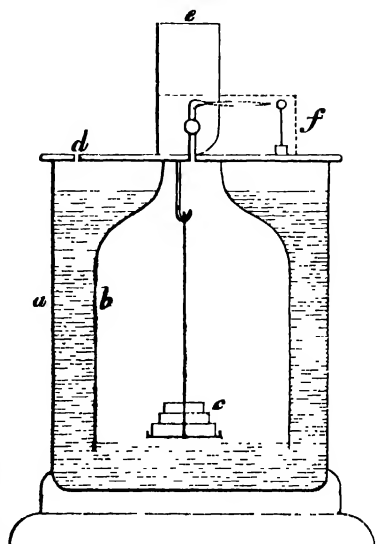
1547. Pleischl has recommended another mode of preparing the platinum in a minute state of division. Unsized paper is moistened and dried three times with a solution of the bichloride, and on burning the paper, the ashes that are left contain the platinum in a fit state for shewing its action on hydrogen and other gases with air or oxygen.

1548. When the platinum is required in an extremely active state it is prepared by fusing crude platinum with twice its weight of zinc, reducing the alloy to powder, and then treating it successively with dilute sulphuric, and dilute nitric acid, assisting the operation, which goes on slowly, with heat. The zinc being removed by the acids, the metallic platinum is left as a dark grey powder, in a very minute state of division, but impure; it is then heated with a solution of potassa, and afterwards washed with water, when it is fit for use.

1549. The spongy platinum, when used for experiments with hydrogen and air or oxygen, is usually made into small balls, about the size of a pea, with one-third, one-half, or two-thirds of its weight of fine clay, moistening the mixture, and drying it slowly. These balls should be exposed to a red-heat in the flame of a spirit-lamp, a short time before they are used, to expel any adhering moisture.

1550. Though platinum acts in a much more energetic manner upon gaseous mixtures when in a spongy form than when aggregated in denser masses, probably on account of the more

extensive surface it presents, still it is not devoid of this pro-
perty even when in the form of wire or foil, or in still larger
masses, provided its surface be absolutely clean. For this pur-
pose it should be boiled successively in a solution of potassa, in
water, in aqueous sulphuric acid, and again in fresh portions of
water several different times, taking care never to touch it di-
rectly with the hand. It has been considered by Faraday, who
has minutely investigated the facts brought forward by Dulong,
Thenard, and Dobereiner, and extended their observations, that
the phenomena arise from the adhesive attraction exerted towards
the gases by the platinum, which brings them sufficiently near to
admit of their powers of chemical action being brought into
play. Spongy platinum can condense large quantities of oxygen
gas ; some have affirmed that it can absorb 200 times its bulk of
this substance.

1551. Take a small piece of thin platinum wire, coil it round
the wick of a spirit-lamp where the spirit burns, so as to make
several turnings, and blow out the flame, after allowing it to
burn for a short time. The heated platinum determines the slow
combination of the spirit with the air at a lower temperature,
and the heat evolved in this manner is sufficient to maintain the
platinum red hot as long as there is any spirit. It should be
covered with a glass funnel, so as to exclude the action of cur-
rents of air.

1552. Oxide of Platinum may be obtained by decomposing
the chloride of platinum by a solution of potassa, the usual re-
action taking place between the water and the chloride. The
products are oxide of platinum and hydrochlorate of potassa.

1553. The Binoxide or Peroxide of Platinum is not easily
obtained in a pure form, from its tendency to form triple salts
when thrown down from any solution in which it may exist. It
has been procured by boiling the bichloride of platinum with
sulphuric acid, decomposing the sulphate of the binoxide pre-
pared in this manner by nitrate of baryta, nitrate of platinum
remaining in solution, and sulphate of baryta being precipitated ;
and adding a sufficient quantity of soda to the solution of the
nitrate, so as to throw down half of the binoxide. If a large
quantity of soda be added, more binoxide is precipitated, but then
it carries along with it a portion of acid.

A Sesquioxide of Platinum has been described by Mr E. Davy.

1554. Platinum may be detected in solution by the dark port-wine colour which solutions of hydriodic acid communicate to any liquids containing it. A solution of potassa gives a yellow-coloured precipitate with strong solutions of platinum ; but with soda, the platinum solution remains perfectly transparent. Hydrosulphuric acid gives a black precipitate. On evaporating any of the solutions of this metal to dryness, metallic platinum may be obtained by exposing the residuum to a strong heat.

1555. Fulminating Platinum may be obtained by adding ammonia to a solution of the sulphate of platinum, and boiling the precipitate that is thrown down in a solution of potassa ; it must then be washed on a filter with water, and allowed to dry. It explodes violently when heated to the temperature of 400°.

1556. Bichloride of Platinum may be prepared by digesting metallic platinum in a mixture of nitric and hydrochloric acids, in the proportions recommended for separating it from its ores (1542), evaporating the solution to dryness by a gentle heat, dissolving the residuum in water, and filtering the solution.

1557. In this process, the chlorine set at liberty by the reaction of the nitric and hydrochloric acids dissolve the platinum, none of these acids having any action upon this metal when perfectly pure ; though it has been ascertained that nitric acid can dissolve it, when an alloy containing a small portion of this metal is digested in it.

1558. The Chloride of Platinum (protochloride) is prepared by evaporating a solution of platinum in nitro-muriatic acid to dryness, treating the residuum with a small quantity of hydrochloric acid and heating it ; care must be taken not to heat it to redness. It may then be washed with water.

1559. Iodide of Platinum is formed by heating iodide of potassium in solution with chloride of platinum. The chloride of potassium is found in solution, and the iodide of platinum is deposited, of a dark tint.

Symb. IK & ClPt = IPt & ClK.

1560. Biniodide or Periodide of Platinum is formed in a similar manner by boiling the bichloride of platinum in a solution of iodide of potassium. Decomposition commences imme-

diately on mixing these materials, but there is little more than a change of colour at first, which gradually assumes a deep port-wine tint, nor is the precipitation rapid till ebullition commences. Two eqs. of iodide of potassium and one of bichloride of platinum, give two of the chloride of potassium and one of biniodide of platinum.

Symb. $2IK$ & $Cl^2Pt = 2ClK$ & $I^2Pt.$

1561. SULPHURET AND BISULPHURET OF PLATINUM may be formed by the reaction of hydrosulphuric acid on the chloride and bichloride of platinum.

CHAP. V.—PALLADIUM, RHODIUM, OSMIUM, AND IRIDIUM.

The following metals being rarely made the subject of experiment by the beginner, a brief notice of them is considered sufficient in this place.

1562. PALLADIUM (*Symb.* Pd. *Eq.* 53.35. *Sp. gr.* 11.5). When a solution of the bicyanide of mercury is added to a neutral solution of platinum-ore, before or after the precipitation of platinum by the addition of hydrochlorate of ammonia, palladium is precipitated in small flocculi in combination with cyanogen. By the action of heat, the cyanogen is expelled and palladium left. In the Philosophical Transactions for 1829, already referred to, Dr Wollaston describes the manner of rendering it malleable, which consists principally in heating it with sulphur at first, so as to produce a sulphuret, heating it again with borax and nitre in a crucible, roasting it afterwards at a dull red-heat, and striking it gently with a hammer, till at last the sulphur is expelled, and it becomes sufficiently dense to become malleable.

1563. Palladium resembles platinum, but is harder and more fusible. It assumes a bluish colour when heated, by absorbing a minute quantity of oxygen, the oxidation being confined to the surface. Sulphuric, nitric, and hydrochloric acids all affect it, but it is dissolved most readily by the nitro-hydrochloric acid. It is precipitated in the metallic form by the green sulphate of iron, and by a number of the metals. The principal compounds

of palladium that have hitherto been described are the oxide and binoxide, the chloride and the bichloride, the sulphuret, and a number of double salts, as the chloride of palladium and potassium. In the metallic form palladium possesses the same power of affecting a mixture of oxygen and hydrogen gases as platinum. The salts formed by its oxide have a fine red colour.

1564. RHODIUM (*Symb.* R. *Eq.* 52.2. *Sp. gr.* 11). This metal is prepared by the following process. Introduce a plate of iron into the solution of the ore of platinum, after the palladium and most of the platinum have been separated. Rhodium is precipitated in the metallic form along with platinum, lead, and copper. Digest the precipitate in dilute nitric acid, by which the lead and copper are removed. The rhodium and platinum must now be combined with chlorine and sodium, by dissolving them in nitro-hydrochloric acid and adding common salt, after which the liquid containing them may be evaporated to dryness. The chloride of sodium and platinum is now removed by alcohol, in which the chloride of sodium and rhodium is insoluble. When the latter is dissolved in water, the rhodium may be precipitated from the solution by metallic zinc.

1565. Rhodium is a hard and brittle metal; its colour is white when fused, requiring a very high temperature for this purpose. Acids do not oxidate or dissolve it when it is pure, though when combined with other metals, as in the platinum-ore, the nitro-hydrochloric acid dissolves it readily. By heating it with nitre or bisulphate of potassa or soda, it is oxidized with facility. Its salts have usually a red or yellow colour.

1566. Two oxides of rhodium have been described, and a number of other combinations, the most important of which is the sulphate of rhodium and potassium, formed by heating rhodium with the bisulphate of potassa, when part of the sulphuric acid is decomposed, oxidating the rhodium and evolving sulphurous acid. It produces a yellow colour when dissolved in water, and from this the presence of rhodium may be indicated in platinum, osmium, or iridium treated with the bisulphate of potassa.

1567. OSMIUM (*Symb.* Os. *Eq.* 99.7; *Sp. gr.* 10). To prepare osmium, the powder that remains after the ore of platinum has been digested in nitro-hydrochloric acid is employed. Three parts of it are mixed with one of nitre, and the mixture heated in a silver crucible till it assumes a pasty consistence, when the

osmic acid begins to be volatilized and to produce its character-
istic odour. Remove the mixture ; when cold, dissolve the ox-
ide of osmium, now in combination with potassa, by water, using
no more than is necessary for this purpose. Then add to the so-
lution aqueous sulphuric acid, previously diluted with its own
weight of water, placing the materials in a retort, from which
the osmium, combined with oxygen, is to be separated by the
application of a sharp heat. It condenses in the receiver which
is attached to the retort, and may be seen in part collecting be-
low the water which is distilled at the same time, and forming
a crystalline solid as it cools. By agitating the osmic acid with
metallic mercury, osmium and oxide of mercury are formed ; by
adding a little hydrochloric acid, the oxide of mercury becomes
water and chloride of mercury, and on the application of heat,
metallic mercury and chloride of mercury are expelled, the me-
tallic osmium being left in the form of a black powder.

1568. Osmium forms four compounds with oxygen, besides
the osmic acid, which contains the largest quantity of this ele-
ment. It inflames and combines with oxygen when heated in
the open air. It attracts oxygen also rapidly from nitric acid
and is dissolved, but when heated to redness and rendered also
more dense and metallic in its appearance by pressure, it is not
affected either in air or nitric acid.

1569. Osmic acid may be obtained by burning osmium, or by
oxidating it by nitre or acids. It is volatile, soluble in water,
and crystallizable. Its vapour is acrid, pungent, and irritating ;
and the metal received the name of osmium from οσμη, odour,
the volatility and odour of the acid it forms with oxygen being
its most characteristic property. As a chemical agent, it re-
sembles acids more than oxides, uniting with alkalis and other
salifiable bases.

1570. Osmic acid in solution is decomposed by sulphurous
acid, the liquid acquiring successively a yellow, brown, green,
and blue tint, as it loses more and more oxygen. The infusion
of galls produces a purplish tint which gradually becomes blue.

1571. IRIDIUM (*Symb.* Ir. *Eq.* 98.8 ; *Sp. gr.* 18.68 *after fusion*).
The insoluble matter that remains, after the compound of osmic
acid and potassa has been removed by water from the mixture
of osmium and iridium fused with nitre (see 1567), contains the
oxide of iridium and potassa. By digesting it in hydrochloric

acid, the iridium may afterwards be precipitated from the solution in the metallic form by the addition of iron, tin, zinc, and other metals, excepting gold and platinum.

1572. Iridium has a brilliant lustre and white colour. It requires the most intense heat of the galvanic battery for its fusion. It is not acted upon by air, even at a high temperature, unless in a minute state of division: It is not affected by the more important acids, and even chlorine, as in the nitro-hydrochloric acid, affects it feebly. Four different oxides have been described, which pass easily into each other, communicating, as they lose or gain oxygen, a variety of tints to the solution. The more usual tints observed are blue, olive, green, and red, and it is from the facility with which these changes are induced, that this metal received the name of iridium, from *iris* the rainbow.

CHAP. VI.—ALLOYS.—AMALGAMS.

1573. ALLOYS are usually prepared by melting together the different metals of which they are composed. Those in which mercury forms a constituent part, which are termed AMALGAMS, may be formed by dissolving in mercury the other metals which they are to contain, when a large proportion of mercury is required; and by adding it to them after melting them, if the quantity of this metal required be comparatively small.

1574. Though numerous metals combine apparently in almost unlimited proportions, still, a close examination of the resulting compounds tends to shew that these new combinations may, in numerous instances, be more correctly considered as definite compounds of portions of the metals, mingled with any excess of either, according to the relative quantities in which they are mixed. In many cases, it has already been ascertained that when the alloys cool and consolidate from a state of fusion induced by heat, different states of consolidation may be observed, any excess of metal becoming solid in general before the alloy assumes the same form, and the temperature becoming stationary for some time from the latent heat evolved as these changes proceed.

1575. Metals, in combining with each other, never lose the

metallic lustre, but in other respects they are in general very considerably changed, more especially in colour, density, hardness, malleability, elasticity, sonorousness, fusibility, proneness to combination in general, and particularly in reference to the action of oxygen and the acids.—Their fusibility is generally increased.—Their density is sometimes greater, sometimes less. —Their malleability is for the most part impaired; even 1–1000dth part of antimony and of some other brittle metals destroys in a great degree the malleability of gold.

1576. By combination their tendency to chemical action is often increased ; an alloy of tin and lead burns like tinder when the combustion has been commenced by heating it in the flame of the blowpipe. Zinc, which dissolves with extreme slowness in dilute sulphuric acid when pure, is dissolved with great rapidity if it be combined with 1–100dth part of iron ; and many have considered that in these cases, an electric action between tne iron and the zinc facilitates much the action of the zinc upon the acid.

In the following paragraphs, the composition of some of the most important alloys is stated, small quantities of which may be easily prepared in the manner described.

1577. Brass is composed of copper and zinc, usually in the proportion of three to one, and occasionally contains a small quantity of other metals. A small quantity may be easily prepared by melting two parts of copper in a crucible, covering it with a little salt and charcoal to protect it from the action of the air, and then putting in gently one part of zinc ; pour out the alloy as soon as the zinc has been completely melted, and the metals have been stirred together with an iron rod. If the zinc and copper be put in together, a considerable quantity of the zinc is lost, being volatilized by the heat.

1578. Twelve parts of copper are rendered yellow by one of zinc ; this tint increases with the proportion of zinc added to the alloy, till equal weights have been combined ; and when the proportion of zinc is still increased, the alloy begins to assume a white appearance, and becomes still more so as the addition of the zinc is continued.

1579. On the large scale, brass is often prepared in a different manner in some manufactories. The impure oxide of zinc is mixed with charcoal and exposed to heat in a covered crucible,

pieces of sheet copper being imbedded with it. The zinc is
reduced and converted into vapour, combining with the copper
as it is disengaged, and forming brass; when the process is
conducted in this manner, the brass is said to be prepared by
cementation.

1580. DUTCH GOLD, PINCHBECK, and TOMBAC, are composed
of the same metals, and generally contain a large quantity of
zinc ; but various proportions are employed.

1581. BRONZE and GUN METAL are alloys of copper and tin ;
the proportions usually employed are about 8 or 9 parts of copper
to 1 of tin.

1582. BELL METAL is made of tin and copper, in various
proportions ; 3 parts of copper and 1 of tin are frequently used.
In the Indian composition, 4 of copper and 1 of tin have been
observed.

1583. SPECULUM METAL, the alloy used for making the specula
of reflecting telescopes, is composed of two parts of copper and
one of tin ; a small quantity of zinc and arsenic, about one
part of each to fifty of the alloy, may be added to it to improve
its lustre.

1584. WHITE COPPER (Chinese) contains in 100 parts, copper
40.4, nickel 31.6, zinc 25.4, and iron 2.6 (Dr Fyfe).   GERMAN
SILVER contains 8 of copper, 3 of nickel, 3½ of zinc, or other
similar proportions of the same ingredients.

1585. TIN and ANTIMONY combine readily when melted to-
gether.   The tin may be separated from the antimony, when the
proportion of the latter is small, by boiling hydrochloric acid.

1586. The term PEWTER is applied to some alloys com-
posed of tin combined with various proportions of other metals.
Antimony, zinc, and copper, are the metals generally employed
for the better kinds of pewter, to which a small proportion of
bismuth is frequently added.   Inferior kinds of pewter contain
about one-fifth of their weight of lead.   *Tin foil* is composed of
tin with a portion of lead.

1587. PLUMBER's SOLDER is composed of equal parts of tin
and lead, or 1 of tin to 2 of lead.   A condensed view of an im-
portant memoir on compounds of lead, tin, and mercury, is given
in Dr Brewster's Journal, vol. i. New Series.

1588. The alloy used for making printing types consists prin-
cipally of about three parts of lead and one of antimony.   .

1589. The Fusible Alloy is prepared by melting in a crucible eight parts of bismuth, five of lead, and three of tin. It fuses at the temperature of 210°. See 1605.

1590. Rose has pointed out a more fusible compound of the same metals. It consists of two parts by weight of bismuth, one of lead, and one of tin ; it melts at a little above 200°.

1591. Arsenic is extremely powerful in rendering the metals with which it combines both fusible and brittle. Even platinum melts at a red-heat when combined with $\frac{1}{10}$th part of arsenic. Copper, with $\frac{1}{10}$th part of arsenic, produces an alloy which is nearly as white as silver.

1592. Lead, Tin, and Antimony also render platinum extremely fusible ; a small quantity of any of these metals falling upon a red-hot platinum crucible renders it in general useless, the alloy of platinum that is formed melting and leaving an aperture in the crucible.

1593. Gold Coin is composed of eleven parts of gold and one of copper.

1594. Standard Silver is an alloy of twelve parts and a third of silver and one of copper.

1595. Iron is coated with tin by dipping it in a melted alloy consisting of ten parts of tin and one of copper. The copper prevents too large a quantity of tin from adhering to the iron ; the melted metal should be covered with a little tallow to prevent it from oxidating. Resin and hydrochlorate of ammonia are much used for the same purpose. Iron goblets are tinned with a similar mixture, which is usually rubbed upon them with a cork after heating them moderately over a small fire worked by a smith's bellows. It is in this manner that *Tinned Iron* is prepared, consisting of thin sheet-iron coated with tin.

1596. Copper vessels are coated with tin by rubbing them overwith hydrochlorate of ammonia, throwing a little powdered resin on them to prevent the copper from acquiring any crust of oxide, and spreading a little melted tin on their surface after exposing them to heat.

1597. Copper may be coated with silver after boiling in water with cream of tartar and alum, by rubbing it with the following mixture made into a paste with water ;—one part of the bichloride of mercury, four of silver precipitated from a solution of the nitrate by copper, sixteen of common salt, and an equal quantity

of the hydrochlorate of ammonia. The copper must then be exposed to a red-heat to drive off the mercury, after which the coating of metallic silver may be polished.

1598. STEEL has been alloyed with minute portions of silicum and aluminum, when it resembles the well-known Indian Steel termed WOOTZ. Stodart and Faraday who prepared this compound, combined steel also with $\frac{1}{500}$th of silver and other metals, by which they communicated to it increased hardness and tenacity. The hardest compound was formed with rhodium.

1599. Steel may be gilded by the ethereal solution of gold prepared in the manner described in 1538, dipping it into the liquid and washing it immediately in water.

1600. Mercury amalgamates readily with a number of metals. Gold and silver are rendered very brittle when combined with a very small quantity of this metal.

1601. Silver, copper, and brass are easily gilded by an amalgam composed of eight parts of mercury and one of gold. This is prepared by heating a mixture of the above metals in these proportions till the gold is completely dissolved, and pouring it immediately into cold water to prevent any loss of mercury. T he metal to be gilded is previously washed with a dilute solution of the nitrate of mercury containing an excess of acid, and the amalgam is laid over as uniformly as possible with a brush made of brass-wire. By exposing it to heat in a furnace or over an open fire, the mercury is dissipated, and the coating of gold is left in combination with the metal, after which it may be polished.

1602. Various compositions have been used as an amalgam for the electrical machine; one part of zinc with an equal weight of tin and two parts of mercury does very well for this purpose.

1603. When mercury is poured on tin-foil it spreads rapidly over its surface, forming an amalgam which is used in making looking-glasses.

1604. An amalgam composed of one part of tin, one of lead, two of bismuth, and four of mercury, is employed for silvering the inside of hollow globes of glass.

1605. If one part of mercury be added to the fusible alloy (1589) an amalgam will be obtained which becomes soft at 162°, and quite fluid at 170°. This is the compound of which fusible spoons are made.

1606. Three parts of mercury combined with one of lead and one of bismuth form an amalgam so fluid, that it may be pressed through chamois leather.

1607. Serullas has described an alloy of potassium and antimony which may be easily prepared. *Mix intimately 1000 grains of cream of tartar and 1000 of metallic antimony reduced to powder. Expose the mixture to a red-heat in a crucible, capable of containing two or three times that quantity, and when it appears quite fluid, remove the crucible, covering it up and allowing it to cool. On breaking the crucible, a conical mass of the alloy will be found. It is very brittle and tarnishes speedily on exposure to the air.

1608. If a small portion be reduced to powder, and thrown into water, hydrogen gas is disengaged, and the solution that is obtained is highly alkaline, potassa being formed by the potassium attracting oxygen.

1609. Many other metals may be combined with potassium or sodium, by heating them with cream of tartar, or carbonate of soda and charcoal, in the manner described in the preceding paragraph. An alloy of bismuth, combined with a considerable quantity of potassium, is obtained by heating 60 parts of calcined cream of tartar with 120 of bismuth and one of nitre. The cream of tartar is calcined by exposing it to a dull red-heat in an iron or earthen vessel, so as to exclude the action of the air.

DIVISION. II.

VEGETABLE AND ANIMAL SUBSTANCES.

PART I.—VEGETABLE SUBSTANCES.

1610. UNDER this title, it is customary to comprehend not merely those proximate principles which are the direct product of vegetation, but also all those that may be obtained most conveniently (and in many cases solely) by the decomposition of these principles, or by their entering into new combinations. No branch of chemistry has been more extended of late years; and indeed, every successive year, for some time past, new views have been developed so rapidly, as to have occasioned considerable embarrassment as to the nomenclature that ought to be adopted in respect to many of the most important combinations.

1611. Vegetable substances, being composed principally of carbon, oxygen and hydrogen, retained together by nicely balanced affinities, are in general very easily decomposed; none of them can bear even a dull red-heat, and most of them suffer decomposition at a much lower temperature. Hence in all experiments with substances belonging to this class, great attention must be paid to the temperature to which they are exposed: the same remark applies to all the proximate principles peculiar to the animal kingdom, which are composed principally of oxygen, hydrogen, carbon, and nitrogen.

1612. Nitrate of silver is the most delicate test of animal or vegetable matter in solution, according to Dr Davy. The solution of the nitrate in pure water, he has remarked, is not altered by exposure to the sun's rays, but when any liquid is added containing the minutest portion of animal or vegetable matter, the discoloration is strong.

ORDER I.—VEGETABLE ACIDS.

1613. The vegetable acids include a variety of compounds which are found in the vegetable kingdom, and are composed principally of oxygen, hydrogen, and carbon. Several of these may be formed artificially, as the *oxalic* and *hydrocyanic* acids, and are not therefore always classed along with the rest. The greater number of them can be obtained in the solid form ; they are mostly soluble in water and in alcohol, have the same general properties as the mineral acids, but are more feeble in their action, and are all decomposed by a red-heat, the carbon and hydrogen which they contain taking fire if they are at the same time exposed freely to the air. When heated in close vessels, so as to exclude the action of the air, the principal products are carbonic acid, carbonic oxide, gases composed of carbon and hydrogen, water, acetic acid, and an empyreumatic oil. By nitric acid, they are in general converted into oxalic acid. When heated with sulphuric acid, they take away a portion of its oxygen, and sulphurous acid is evolved.

1614. Among the various researches connected with the history of vegetable acids, few are of greater novelty or interest than those of Pelouze, in which, by a process termed the WHITE DISTILLATION, in consequence of no carbon being separated, and no dark tint therefore communicated to the materials, they can be resolved by the action of a carefully regulated temperature into new acids ; water, carbonic acid, or both, being at the same time developed. Nor is it unreasonable to suppose, that the principle he has pointed out may be greatly extended, and that, by the application of varied, but more precise and regulated temperatures than have hitherto been in general sustained in the examination of organic and inorganic compounds, a great addition will be made to the power that is already attained of producing combinations and decompositions.

1. Acetic Acid.

Symb. A, or $O^3C^4H^3$.   *Eq. by W.* $51.48 = O.24 + C.24.48 + H.3$.
*The strongest acid that can be obtained when not in combination
with a salifiable base is composed of one equivalent of dry acid
and one of water.*

1615. Acetic acid exists in small quantities in the sap of many
plants.   It is usually prepared by exposing liquids that have
undergone the vinous fermentation freely to the air, at a tempe-
rature between 70° and 90°.   Many vegetable juices which have
never undergone the vinous fermentation are capable of passing
at once to the acetous fermentation, and the action is promoted
by a little ferment taken from a liquid in the same state of fer-
mentation.   A large quantity of oxygen is absorbed, and the
vinegar which is produced consists of acetic acid, water, muci-
laginous matters that have not been decomposed, and a little
alcohol.   Every two eqs. of alcohol and four of oxygen produce
three of water and one of acetic acid.

$Symb.$ 2 (OC^2H^3) & $O^4 = 3 \cdot H$ & $O^5C^4H^3$.

1616. Acetic acid may be produced also by the slow combus-
tion of alcohol, especially when assisted by the action of spongy
platinum.

1617. Acetic acid is now prepared in large quantities by ex-
posing wood to heat in iron-vessels.   Charcoal remains ; much
watery vapour, and inflammable gases are disengaged ; and the
products collected in the receiver consist of a dilute acetic acid,
tar, an oily matter, and pyroxilic spirit.   The tarry matter is
removed, and lime added to the acid fluid till it is neutralized ;
on exposing it to heat, the pyroxilic spirit is disengaged, and
may be collected in a receiver.   To the solution of the acetate
of lime, sulphate of soda is then added as long as any precipita-
tion takes place ; sulphate of lime is thus thrown down, and
acetate of soda remains in solution.   On evaporating it to dry-
ness, and heating it to about 540°, the impurities still associated
with it are in a great measure decomposed ; by solution in water,
filtration, and evaporation, it is obtained free from charry mat-
ter ; and, on heating it with sulphuric acid in a retort, sulphate
of soda is formed, and the acetic acid is condensed in a receiver

in combination with the water previously combined with the sulphuric acid.

1618. According to the London College, two pounds of acetate of soda are subjected to heat in a retort after adding nine ounces of aqueous sulphuric acid previously diluted with nine fluid ounces of water. The acetate of soda contains six eqs. of water when crystallized. 100 parts of the acid thus prepared contain 30.8 of dry acetic acid; and 15 parts of this acid and 85 of water are equal in strength to distilled vinegar (Phillips).

1619. Acetic acid contains occasionally a little sulphurous acid, from which it may be separated by a second distillation, mixing it previously with a little of the binoxide of manganese, by which the sulphurous acid is converted into sulphate of manganese. *Symb.* :S& :Mn = :S·Mn.

1620. The Edinburgh College directs it to be prepared by putting six parts of the dry sulphate of iron and five parts of the acetate of lead into a retort after they have been well mixed, and distilling from a sand-bath till no more acid is disengaged, condensing the product in a receiver. Here the sulphuric acid of the sulphate unites with the oxide of lead in the acetate, and disengages the acetic acid, oxide of iron and sulphate of lead remaining in the retort.

1621. Strong acetic acid may be procured also by exposing some of the metallic acetates to heat without the addition of any acid. To prepare a little in this manner, fill a small green glass-retort half full of the acetate of copper, and expose it to heat over a good charcoal chauffer, condensing the product in the usual way; if a green glass-retort cannot be obtained, take a flint glass-retort, and heat it by a sand-bath, or coat it with plaster of Paris, and then the chauffer may be used. The acid obtained in this manner is never pure, being always mixed with pyroacetic spirit, formed in consequence of a part of it being decomposed. This process is now rarely resorted to, since the decomposition of the acetate of soda has been introduced.

1622. Acetic acid and water unite in all proportions, and the specific gravity of the compound is sometimes the same, though very different quantities of acid and water may be combined together. The following table shews its specific gravity when combined with one, four, and even seven atoms of water.—(Dr Thomson.)

Specific gravity at 60°.	Acid.	Water.
1.06296	1 equivalent	1 equivalent
1.07132	1	4 ......
1.06349	1	7 ......

Its density alone, therefore, cannot be taken as an index of its strength.

1623. The weak acetic acid of the different Colleges is prepared by distilling vinegar, rejecting the first part out of every eight or ten, as it contains less acid and a portion of alcohol ; the next five or six are the weak acetic acid of the pharmacopœias, and the distillation is stopped when they have come over ; or the product is collected in a different receiver, as it then has an empyreumatic odour, from the mucilaginous matters which it contains beginning to be decomposed. Its specific gravity varies from 1.006 to 1.009 ; 1000 grains of acid of the latter specific gravity are neutralized by 145 grains of the crystallized carbonate of soda. It cannot be rendered stronger by distillation alone, as the acid and the water rise together on the application of heat. By exposing vinegar or a weak acid to cold, most of the water freezes, leaving a stronger acid which may be separated by decantation.

1624. The method of estimating the strength of acetic acid consists in ascertaining the quantity of crystallized carbonate of soda which it can neutralize, 51.48 parts (one equivalent) of dry acid being required for one equivalent of the carbonate.

1625. Strong acetic acid has a very pungent and agreeable odour, and volatilizes rapidly when exposed to a moderate heat, producing an inflammable vapour, which is easily kindled. It crystallizes at a low temperature, and remains solid till heated again to 50°. Its acid properties are very well marked, neutralizing completely the different salifiable bases, and forming salts that are decomposed by heat, and easily distinguished by the odour of acetic acid which they emit when sulphuric acid is poured upon them. It reddens the vegetable blues powerfully, oxidates iron, copper, lead, zinc, and some other metals, and raises a blister on the skin when kept in contact with it for some time. It dissolves volatile oils, camphor, and the active principles of some of the most powerful vegetable medicines.

1626. Acetic acid is often sold in a very impure state. Sulphuric and sulphurous acids may be detected by acetate of lead, which gives a white precipitate when they are present. An excess of ammonia renders it blue when it contains copper, and lead may be detected by hydrosulphuric acid, which gives a black precipitate. When pure, it leaves no residuum on evaporation.

2. TARTARIC ACID.

Symb. T or $O^5C^4H^2$. *Eq. by W.* 66.48 = 0.40 + C.24.48 + H.2. *Eq. of crystallized Tartaric Acid* 75.48 *(dry acid* 66.48 + 9 *water). It is soluble in five parts of water at* 60°.

1627. Tartaric acid is prepared by pouring 49.1 parts by weight of sulphuric acid on 130.98 of the common tartrate of lime, diffused through three or four times its weight of boiling water, stirring the mixture occasionally for a day or two after it has been well rubbed in a mortar, and evaporating the liquid obtained by filtration through a linen bag. 130.98 parts of the common tartrate of lime must be used, as they contain 94.98 of dry tartrate and 36 of water. One equivalent of the tartrate of lime (94.98) is composed of 66.48 of acid and 28.5 of lime ; and the 40.1 of dry sulphuric acid in the quantity employed combine with the lime, and form 68.6 of the sulphate of lime, while the tartaric acid is disengaged, and remains in solution. Very little of the sulphate of lime is dissolved, as it requires a large quantity of water for its solution, and the tartaric acid crystallizes after the liquid is evaporated, which should be done in an earthen evaporating basin over a sand-bath, with a very moderate heat. The sulphate of lime in the liquid is deposited after the evaporation has been continued for some time, and should be separated by pouring it into another vessel ; when the solution has assumed a syrupy consistence, it may be set aside to crystallize. The crystals must be purified by a second crystallization.

1628. The tartrate of lime is prepared by mixing chalk (carbonate of lime) in fine powder intimately with four times its weight of cream of tartar (composed of 180.16 bitartrate of potassa + 18 water), and throwing the mixture into 10 or 12

times its weight of boiling water, adding small quantities at a time, that the effervescence which takes place may not be too violent. 94.98 parts of dry tartrate of lime are formed, 113.68 parts of neutral tartrate of potassa remain in solution, and 22 of carbonic acid are disengaged. The following diagram gives a view of the reaction that takes place, supposing the whole of the tartrate of lime to be precipitated; a small portion generally remains in solution.

Fig. 223.

Before Decomposition.		After Decomposition.
180.16 Bitartrate of Potassa	Potassa.........47.2 Tartaric A...66.48 Tartaric A...66.48	113.68 Tartrate of Potassa.
50.62 Carbonate of Lime	Carbonic A. 22.12 Lime......... 28.5	22.12 Carbonic Acid. 94.98 Tartrate of Lime.
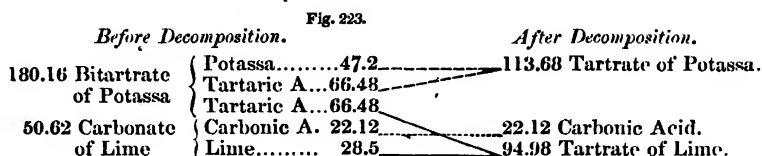
1629. An additional quantity of tartrate of lime may be obtained by adding a solution of the hydrochlorate of lime to the solution of the tartrate of potassa as long as any precipitation takes place; the proportions in which the materials react on one another are represented below.

Fig. 224.

Before Decomposition.		After Decomposition.
113.68 Tartrate of Potassa	Potassa ....47.2 Tartaric A. 66.48	83.7 Hydrochl. of Potassa.
65 Hydrochlo. of Lime	Hydroch. A...36.5 Lime 28.5	94.98 Tartrate of Lime.
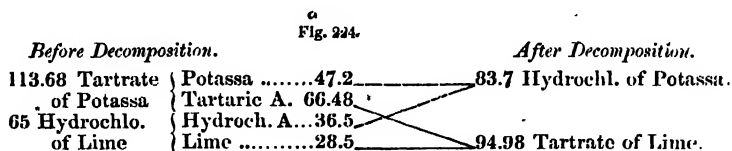
1630. Tartaric acid crystallizes in prisms; it is soluble in five parts of cold and in two of boiling water; its solution in water is very sour, but has an agreeable taste when sufficiently diluted; it is also soluble in alcohol. When exposed to heat it is completely decomposed; and by destructive distillation a peculiar acid is formed, which has been termed from its mode of preparation the Pyrotartaric acid. Tartaric acid is particularly distinguished by forming with potassa a salt that is sparingly soluble (bitartrate of potassa) when added in excess to this alkali, though the neutral tartrate of potassa and the tartrate and bitartrate of soda are very soluble.

1631. Tartaric acid and many of its salts have the property of dissolving several metallic oxides, and of preventing them from being precipitated from their solutions by substances which

are in general capable of producing this effect. This may be easily seen by adding a little tartaric acid to a solution of the sulphate of iron, and then some ammonia in excess, which will not precipitate the oxide of iron after the tartaric acid has been mixed with the sulphate.

1632. Tartaric acid decomposes carbonates with effervescence, and precipitates potassa from its solutions when they are not diluted with water, small crystals of the bitartrate being formed.

3. CITRIC ACID.

Symb. O^{4}C^{1}H^2. *Eq. by W.* 58.48 = O.32 + C.24.48 + H.2. *Eq. of crystallized citric acid* 76.48 *(dry acid*-58.48 + 18 *water)* ; *it is soluble in less than its own weight of water at* 60°, *and boiling water dissolves about twice as much ; it is also soluble in alcohol.*

1633. Citric acid is prepared by diffusing 86.98 parts (one equivalent) of the citrate of lime through water, and decomposing them with 49.1 of sulphuric acid, conducting the process in the manner directed for the preparation of tartaric acid. The sulphuric acid mixed with the citrate of lime forms sulphate of lime, the citric acid remaining in solution. By filtering and evaporating the solution in the same manner as the solution of tartaric acid, crystals are obtained, which must be purified by dissolving them in water and filtering the solution through paper, after which crystals may be procured as before.

1634. The citrate of lime is obtained by adding chalk in fine powder to the juice of the lime or lemon as long as any effervescence takes place ; and is separated from the mucilaginous matters which the juice contains along with the acid, by washing it repeatedly with water. In this process, the citric acid disengages the carbonic acid of the chalk as it combines with the lime. The specific gravity of the lemon juice varies considerably, and according to Dr Henry, a wine gallon usually affords from six to eight ounces avoirdupois of the crystallized acid.

1635. Citric acid bears a great resemblance to tartaric acid, but may be easily distinguished from it by carbonate of potassa, with which the solution of citric acid gives no precipitate when

added in excess. Tartaric acid may be detected in this manner, if it has been mixed with citric acid, a practice that is occasionally followed, as it is much cheaper than the citric acid.

1636. A new acid, the PYROCITRIC, is formed when citric acid is exposed to the action of heat.

4. OXALIC ACID.

Symb. $\ddot{C}^2$. *Eq. by W.* $36.24 = O.24 + C.12.24$. *Symb. of teraqueous or Cr. Oxalic Acid* $3 \cdot H + \ddot{C}^2$. *It is soluble in* 1.5 *parts of cold water, and in less than its own weight of boiling water ; it is also soluble in alcohol.*

1637. Oxalic acid exists in the juice of the *Oxalis acetosella* or wood-sorrel and of many other plants, in combination with potassa or lime ; but it is almost always prepared by digesting sugar or waste syrups in nitric acid, or by heating saw-dust with potassa.

1638. To illustrate the process by which it is obtained from sugar and nitric acid, fill a flask or retort about a third full of binaqueous nitric acid, diluted with one-half of its bulk of water (an ounce or two will be a sufficient quantity on the small scale), and add, in small quantities at a time, a sixth part of its weight of refined sugar coarsely powdered. *If necessary*, apply a gentle heat to commence the action by a lamp or chauffer, which must then be removed till it becomes feeble : and evaporate the remaining liquid till it acquires the consistence of syrup, when it may be set aside to crystallize. Every 100 parts of sugar give about 60 of crystallized oxalic acid ; it must be purified by solution in water and a second crystallization. When this process is adopted on the large scale, molasses may be used instead of refined sugar.

1639. The precise nature of the reaction which takes place has not been very minutely investigated ; small quantities of malic and acetic acids are formed along with the oxalic acid. As oxalic acid contains no hydrogen, and the quantity formed is much less than the weight of sugar employed, its formation must depend on the oxygen of the nitric acid attracting the hydrogen and part of the carbon from the saccharine matter.

A large quantity of nitrous acid, binoxide of nitrogen, and carbonic acid, is disengaged ; the fumes are very offensive, and the flask should be placed where they may be carried off. Many other substances give oxalic acid when treated in the same manner, as wool, hair, silk, tendon, alcohol, and gum arabic.

1640. Starch has occasionally been substituted for sugar, four parts of acid being generally employed with one of starch, and added in successive portions. The drainings of the crystals give an additional quantity when treated with more nitric acid.

1641. When oxalic acid is prepared by heating saw-dust or other vegetable matters, along with lime or potassa, it must be exposed to a temperature between 400° and 500°.

1642. The composition of oxalic acid is beautifully illustrated by heating it in a glass tubulated retort with five or six times its weight of aqueous sulphuric acid ; all the water of crystallization is withdrawn by this acid, while the carbon and oxygen are resolved into equal measures of carbonic oxide and carbonic acid gases. 250 grains of the common oxalic acid will be sufficient for this purpose, heating them with the sulphuric acid in a retort capable of containing six or seven ounce measures when full, and collecting the gases that are evolved in jars over water at a common pneumatic trough. The carbonic oxide and acid gases are mixed together ; the former burns with a blue flame on applying a light, and the carbonic acid gas may be detected by lime water, with which it gives a copious white precipitate.

1643. Oxalic acid crystallizes in four and six sided prisms, has an extremely sour taste, and reddens sensibly litmus paper even when dissolved in 200,000 parts of water. It is resolved into carbonic acid and carbonic oxide when exposed to a high temperature, but may be sublimed completely without further decomposition than losing two eqs. of its water of crystallization, if the heat does not exceed 330°, condensing in crystals upon the upper part of the flask in which it is heated. When the heat is rapidly urged it rises to 248° soon, and then increases to 266°, every twelve equivalents of the Cr. acid producing 12 of carbonic acid, 10 of carbonic oxide, 35 of water, and 1 of formic acid.

Symb. $12 (3 \cdot H + \ddot{C}^2) = 12 \ddot{C}, 10 \cdot C, 35 \cdot H,$ and $\ddot{C}^2 H.$

1644. It gives a white precipitate with lime-water, the oxa-

late of lime being very insoluble.   It is also precipitated by ni-
trate of silver, oxalate of silver being thrown down.   This salt is
decomposed with detonation by heat, metallic silver being left.

1645. Oxalic acid is a powerful poison, and has proved fatal
occasionally, even when diluted with a large quantity of water
and taken as an acidulous drink ; two or three drachms are suf-
ficient to produce death.   The soluble oxalates are also poison-
ous.   Drs Christison and Coindet, in an able memoir on poi-
soning by oxalic acid, in the Edinburgh Medical and Surgical
Journal, have shewn that chalk and magnesia are certain anti-
dotes to this poison when administered in proper time, the oxa-
lates of lime and magnesia which are formed being quite inert.

1646. Most cases of poisoning by this acid have arisen from
its having been mistaken for Epsom salts (sulphate of magne-
sia), to which it bears a considerable resemblance in external
appearance when the crystals are small ; they are easily distin-
guished from each other, however, by a number of simple tests.
Oxalic acid has a very sour taste, reddens the vegetable blues,
effervesces with a solution of the carbonate of potassa or of soda,
and is completely dissipated by heat ; sulphate of magnesia,
again, has a pure bitter taste, does not affect the vegetable co-
lours, gives a white precipitate with solutions of the alkaline
carbonates mentioned, but does not produce any effervescence,
and parts with its water of crystallization on exposure to heat,
without undergoing any further change.   An emetic should be
taken and large draughts of warm water to promote its action,
in the first instance, or the stomach pump may be employed.

1647. All the oxalates are decomposed by heat.   Those that
are soluble in water give a copious precipitate with salts of
lime ; and on digesting it with a sufficient quantity of sulphuric
acid, sulphate of lime is formed, the oxalic acid remaining in
solution.

1648. Oxalate of lime, precipitated at 60° and dried, contains
two eqs. of water ; dried at 212° it contains one ; and dried at
500° it is anhydrous.

1649. OXAMIDE is the name given to a compound produced
by distillation from the oxalate of ammonia.   Its symbol is
$O^2C^2H^2N$.

1650. Solutions of oxalic acid give crystals of oxalate of am-
monia with extreme facility, when neutralized by this alkali and
concentrated.

5. Benzoic Acid.

Symb. B, or $O^3C^{14}H^5$*. Eq. by W.* 114.68 $=$ 0.24 $+$ C.85.68 $+$ H.5.
Fuses at 230°*, and at the same time begins to sublime. It re-*
quires 24 *parts of boiling water for its solution, and is very spa-*
ringly soluble in cold water. It is dissolved by alcohol.

1651. Benzoic acid is obtained by sublimation from gum-ben-
zoin, in which it exists mixed with resin and other vegetable
matters, and this is said to be the most productive process and
also the least troublesome. An ounce or two of the gum re-
duced to powder may be put into a glass.or earthenware vessel,
and a tall cone of paper placed over it. Heat is applied by a
sand-bath, and the temperature is gradually raised till the acid
rises in white fumes and condenses on the sides of the paper.

1652. Another process for obtaining this acid is preferred by
many, as it is not then contaminated with any empyreumatic
oil, which is always mixed with it when prepared by sublima-
tion. The Edinburgh College directs three parts of the gum
to be reduced to a fine powder and intimately mixed with one
part of the carbonate of soda. The mixture is then boiled for
half an hour in twenty-four parts of water, the liquor poured
off, and the residuum boiled again with nine parts of water.
The benzoic acid combines with the soda of the carbonate,
forming benzoate of soda, which remains in solution, and the
carbonic acid is separated with effervescence ; the other parts
of the benzoin are not dissolved. The mixed decoctions are
then filtered and evaporated till only two parts remain, and on
adding sulphuric acid, previously diluted with seven parts of
water, as long as any precipitation takes place, the benzoic acid
is thrown down, and sulphate of soda remains in the liquid, from
which the benzoic acid is separated by filtration. It is after-
wards dried and sublimed to obtain it in the light feathery and
crystalline form in which it is known by the name of **Flowers
of Benzoin**. Both processes may be easily conducted with an
ounce or two of the gum.

1653. A modification of Scheele's process for preparing ben-
zoic acid has been adopted by the Dublin College. Five parts

of gum-benzoin are triturated with one of lime, and boiled in about 100 parts of water. The liquid is then decanted, and the residuum boiled with 70 parts of water, after which these liquids are mixed, evaporated to a half, and filtered through paper. In this manner a solution of the benzoate of lime is procured, and on decomposing it by adding one part of hydrochloric acid, the benzoic acid is precipitated, and hydrochlorate of lime remains in solution. By filtration, the hydrochlorate of lime is separated, after which the benzoic acid may be washed with a little cold water, and then dried and sublimed.

1654. The benzoic acid procured by either of these processes may be sublimed in the manner described in 1651, page 453, or merely by heating it in a glass-flask, the upper part of which is not exposed to the direct action of the heat; a lamp or small chauffer will do very well. The crystals of benzoic acid collect in the upper part of the flask, and may be withdrawn by shaking it with the mouth downwards over a sheet of paper.

1655. Benzoic acid exists in several other productions of the vegetable world, and in the urine of children and graminivorous animals.

1656. Pure benzoic acid is very white, and has a shining lustre. Its odour is fragrant and peculiar, but M. Giese attributes this to the presence of a small portion of oil. It burns with a yellow flame when exposed suddenly to a strong heat.

1657. Benzoic acid, when combined with soda or ammonia, has the property of separating the peroxide of iron completely from its neutral solutions, and is used frequently for this purpose in analytical chemistry, especially when the iron is associated with manganese, which it does not precipitate.

1658. Benzule is the name given to a principle which is represented by $O^2C^{14}H^5$, and, according to Liebig and Wohler, benzoic acid may be represented as an oxide of benzule.

6. Gallic Acid, Succinic Acid, &c.

1659. Gallic Acid. (*Symb. G,* or $O^5C^7H^3$. *Eq.* 85.84.) It is usually obtained by exposing an infusion of gall-nuts to the air for six or eight weeks, when the acid is deposited in small crystals. More may be obtained by evaporating the liquid still

remaining to the consistence of syrup ; mixed with colouring matter, however, and a peculiar acid which Braconnot has termed the Ellagic, which contains an equivalent less of oxygen and hydrogen than the gallic acid.   Gallic acid crystals dissolve in 100 parts of cold water ; they are also soluble in alcohol.   It takes fire when exposed to heat ; and is distinguished by the very dark precipitate that it gives with salts of iron, which is the basis of black ink.   When combined with tannin, with which it is usually associated, it has the important property of preci-pitating most of the metallic oxides from their solutions, even when they are united with the more powerful acids, and is ac-cordingly much employed as a reagent.   For this purpose an infusion of gall-nuts is frequently used, being usually made by pouring a few ounces of boiling water over every ounce of galls, and allowing the mixture to stand for some time before filtra-tion.   The tincture is often preferred, as it is less liable to be decomposed on being kept ; it may be prepared by digesting the powder of the gall-nuts in alcohol.

1660. Pyrogallic Acid is formed when gallic acid is exposed to a temperature between 410° and 420°, being then separated by sublimation.   Metagallic acid is produced when the tempe-rature is increased to 264°.

1661. Succinic Acid (*Symb. S*, or $O^3C^4H^2$. *Eq.* 50.48) is prepared by exposing amber, after it has been reduced to powder and mixed with an equal weight of sand, to heat in a green glass or coated flint-glass retort, heating the mixture by a chauffer, or on the large scale by a sand-bath.   A consider-able quantity of oily matter comes over, and succinic acid is deposited in crystals on the neck of the retort and sides of the receiver.   They are purified by dissolving them in nitric acid by the application of heat, and evaporating the liquid to dryness, taking care not to expose the residuum to a tempera-ture sufficient to sublime it ; in this manner the empyreumatic oily matter is completely decomposed, and the succinic acid left quite pure.   The crystals contain one eq. of water.   It may be obtained anhydrous, by distillation after mixing it with dry phosphoric acid.   In combination with ammonia, it is used to separate iron from some of its combinations in analytical processes.

1662. BOLETIC ACID is obtained from the juice of the *Boletus pseudo-igniarius.*

1663. IGASURIC ACID exists in the nux vomica in combination with strychnia. (See Strychnia.)

1664. CAMPHORIC ACID is prepared by digesting camphor in nitric acid.

1665. MALIC ACID is found in unripe apples, and in the juice of a great number of fruits. The acid obtained from the berries of the *Sorbus aucuparia* was formerly termed SORBIC ACID, but it has now been proved to be malic acid. Distilled at 349°, Pelouze found that it was resolved into two isomeric acids, the EQUISETIC or MALEIC, and the FUMARIC or PARAMALEIC.

1666. MUCIC or SACCHOLACTIC ACID is formed by digesting sugar of milk or gum in nitric acid. PARAMUCIC acid is the name given to another acid, isomeric with the mucic acid. When exposed to heat in close vessels, a peculiar acid, which has been termed the PYROMUCIC, is obtained.

1667. OXALHYDRIC ACID is obtained by the action of diluted nitric acid upon gum and a number of other substances, and is now considered to be essentially different from the mucic acid.

1668. MELLITIC ACID is obtained by boiling the *Honey-Stone* in 60 or 70 parts of water and concentrating the solution, when it is deposited in small crystals. The large quantity of water employed is found sufficient to separate it from the alumina with which it is combined in the honey-stone.

1669. MOROXYLIC ACID was discovered in combination with lime, exuding from the bark of the white mulberry tree. MENISPERMIC ACID is found in the seeds of the *Menispermum cocculus,* and FUNGIC ACID in the *Merulius cantharellus* and several other plants. CARBAZOTIC acid is obtained by the action of nitric acid on indigo.

1670. PECTIC ACID is found in a number of plants, and is particularly distinguished by its tendency to form a coagulum or gelatinous mass with water.

1671. Numerous other vegetable acids might be mentioned, but it will be sufficient to notice the more important under the history of the various substances with which they are generally associated, as the meconic acid under morphia, these substances being associated together in opium.

7. HYDROCYANIC OR PRUSSIC ACID.

The history of Hydrocyanic Acid has now become so extended by recent researches, that it will be considered most conveniently under different sections.

CYANOGEN, OR BICARBURET OF NITROGEN.

Symb. C^2N. *Eq. by W.* $26.44 = C.12.24 + 14.2$ N. *Eq. by Volume* □ *(one measure).* *Sp. gr.* 1.82. 100 *c. i. weigh* 56.5 *grains.* *Gaseous, transparent, colourless, inflammable, burning with a beautiful purplish flame.* *Condensed into the liquid form at* 45°, *by a pressure of* 3.6 *atmospheres.*

1672. The bicarburet of nitrogen, discovered by Gay Lussac, received the name of Cyanogen from χυανος, purple, being one of the essential ingredients in Prussian blue. It is obtained in the gaseous form by exposing the bicyanide of mercury (a compound of metallic mercury and cyanogen) to heat in a small glass-retort, and collecting the gas that is disengaged at the mercurial trough. Green glass-retorts should be taken when they can be obtained, or an iron tube-retort ; an ounce of the bicyanide gives a considerable quantity of gas, and when only a very small quantity is required, it may be procured by heating a little of the bicyanide in a bent tube with a spirit-lamp.

In conducting this process, the bicyanide should not fill the retort more than half-full, and ought to be perfectly dry. The heat applied should be sufficient to expel the cyanogen slowly and steadily, as it is liable to be decomposed by a higher temperature. The mercury is volatilized as the gas is disengaged. The bicyanide melts and becomes black before it is decomposed. Towards the end of the process, a black-looking substance is formed, consisting, according to Mr Johnston, of the same elements as cyanogen, united in the same proportion, and termed PARACYANOGEN.

1673. The BICYANIDE of MERCURY is prepared by boiling 8 parts of purified Prussian blue, 11 of the peroxide (binoxide) of

mercury, and 30 of water, in an earthen evaporating basin, reducing both to a fine powder previously, and continuing the heat for ten or fifteen minutes. The Prussian blue consists of iron, cyanogen, oxygen, and hydrogen, and is obtained sufficiently pure for this purpose by digesting the Prussian blue of commerce in hydrochloric acid diluted with ten times its bulk of water, which removes the alumina and other foreign matters it usually contains, washing it repeatedly with water till the excess of acid has been removed. In this process, each equivalent of peroxide of mercury acquires two equivalents of hydrocyanic acid from the Prussian blue, and is converted into biperhydrocyanate of mercury. The biperhydrocyanate remaining in solution is separated by filtration, and on evaporating the liquid till a pellicle appears on its surface, crystals of the bicyanide of mercury are obtained when it cools; the two equivalents of hydrogen in the two of hydrocyanic acid, uniting with the oxygen of the peroxide, while the cyanogen goes to the metallic mercury, in the manner shewn in the following diagram :

Fig. 225.

Before Decomposition.		*After Decomposition.*
Hydrocyanic Acid 2 equiv. = 27.44 × 2	{ Hyd. 1 { Hyd. 1 { Cyan. 26.44 { Cyan. 26.44	9 Water.
Peroxide of Mercury 219	{ Oxyg. 8 { Oxyg. 8 { Merc. 203	255.88 Bicyan. of Merc.

Symb. $2(HC^2N) + Hg = 2 \cdot H \& 2(C^2N) + Hg.$
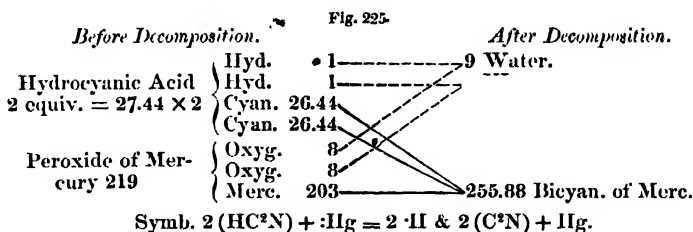
1674. Some chemists prefer preparing Prussian blue by the action of a solution of the ferrocyanate of potassa, added to a solution of a hydrochlorate of the peroxide of iron, as long as any precipitation takes place. It is obtained in this manner of a fine deep blue colour at once, and is purified by agitating it with water in a large jar two or three times, decanting the water when the precipitate subsides. It is afterwards to be dried before the fire on a linen cloth till it becomes hard and brittle. When prepared in this way, fine crystals of the bicyanide of mercury are procured at once on filtering the liquid prepared by boiling it with the peroxide of mercury in the proportions recommended; and the saturated solution which remains after crystallization gives an additional quantity on further evaporation.

1675. When the solution contains an excess of peroxide of mercury, it has been recommended to neutralize it by pure hydrocyanic or hydrochloric acid ; small scaly-looking crystals being formed, instead of long slender prisms, when this is not attended to. These small crystals do not give any cyanogen on exposing them to heat. They are composed of the bicyanide and peroxide of mercury ; and when decomposed by heat, the oxygen of the oxide uniting with the carbon of the cyanogen forms carbonic acid and carbonic oxide, nitrogen gas being liberated at the same time.

1676. Another process for the preparation of the bicyanide of mercury consists in adding the peroxide of mercury finely pounded in minute successive portions to hydrocyanic acid diluted with twenty parts of water. The same changes take place between the peroxide and the hydrocyanic acid which have already been explained. In conducting this process, the mixture must be repeatedly agitated, and afterwards heated. Strong hydrocyanic acid must not be employed, as when it comes in contact with the peroxide of mercury in a minute state of division, considerable heat is produced, and it might be converted rapidly into vapour with great danger to the operator. In heating and concentrating the solution, also, unless all excess of the acid be combined with the peroxide previously, the fumes that escape must be carried off carefully at a ventilator.

1677. Little or no cyanogen is obtained from the bicyanide when it is moist ; the hydrogen of the water converts one part of the cyanogen into hydrocyanic acid, and forms ammonia with the nitrogen of another portion, the oxygen combining at the same time with the carbon and producing carbonic acid.

1678. Cyanogen gas is transparent and colourless, and has a peculiar pungent odour. It can bear a much higher temperature than most other compound gases containing carbon without decomposition. It cannot support combustion, but burns with a beautiful purple flame ; a small jar filled with it at the mercurial trough will be sufficient to shew its inflammability, or it may be inflamed as it is disengaged from a small tube, the open extremity having been drawn out to a small point at the blowpipe. It consumes twice its volume of oxygen during its combustion, each equivalent of carbon taking two of oxygen and forming carbonic acid gas, while the nitrogen is disengaged.

When it is mixed with pure oxygen in this proportion, the mixture must be put into the detonating bottle before it is inflamed.

1679. Water can absorb more than four times its volume of this gas, and alcohol can dissolve twenty-three times its volume. Cyanogen combines with the metals forming a class of compounds which have been called Cyanides, and Cyanurets. It also forms acids by combining with oxygen and hydrogen, and a number of other compounds, the most important of which are described in the subsequent sections.

HYDROCYANIC OR PRUSSIC ACID.

Symb. HC^2N. *Eq. by W.* 27.44 = *cyanogen* 26.44 + 1 *hydrogen : by volume* ☐☐ *(two measures) ; specific gravity of the liquid acid* 0.7508 *at* 45° ; *it boils at the temperature of* 80° *and freezes at zero. Specific gravity of the vapour of hydrocyanic acid* 0.94. *Weight of* 100 *c. i.* 29.3 *grains.*

1680. As hydrocyanic acid is a powerful poison, acting perhaps more instantaneously than any other, all experiments with it must be performed with the greatest caution. Several fatal accidents have already occurred from persons operating with it who were not fully aware of its nature ; and even the fumes of the acid are apt to induce a state of stupor when they are incautiously inhaled, though diluted with a large quantity of air.

1681. Vauquelin's process for preparing the strong acid consists in transmitting a stream of hydrosulphuric acid slowly over the bicyanide of mercury, heated gently in a tube (which may be about 18 inches long and at least half an inch in diameter internally) nearly filled with this substance, and placed horizon-

Fig. 226.
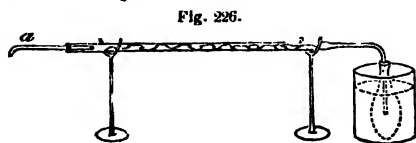
tally, in the manner represented in figure 226. The hydrosulphuric acid is passed over it till the whole of the bicyanide has become

black, none of this gas escaping through the other extremity of the tube till all the bicyanide is decomposed ; and whenever the odour of hydrosulphuric acid is perceived at the mouth of the

receiver, the tube *a*, connected with the apparatus in which the gas is produced, is withdrawn, and the extremity of the other tube into which it was previously inserted is closed with a little plaster of Paris, or with a glass-stopper luted tightly to it.   It is heated gently when the lute has set, and the hydrocyanic acid which has been formed is volatilized and condensed in a small receiver placed in a freezing mixture.

1682. One equivalent of the bicyanide requires two equivalents of hydrosulphuric acid for its complete decomposition, and two equivalents of hydrocyanic acid and one of the bisulphuret of mercury are obtained ; the following diagram gives a view of the action that takes place :—

Fig. 227.

Before Decomposition.   *After Decomposition.* *

Hydrosulphuric ⎧ Hydrog. 1 - - - - - - - → 27.44 Hydrocyanic Acid.
   Acid 2 eqs. = ⎪ Hydrog. 1   - - ⟋ ⟍ 27.44 Hydrocyanic Acid.
   17.1 × 2.   ⎨ Sulph. 16.1
                 ⎩ Sulph. 16.1

Bicyanide of   ⎧ Cyan. 26.44
Mercury 255.88 ⎨ Cyan. 26.44
                ⎩ Merc.   203 - - - - - - - → 235.2 Bisulphuret of Mercury.

Symb. 2 HS & 2 (C^2N) + Hg = 2 (HC^2N) & S^2Hg.
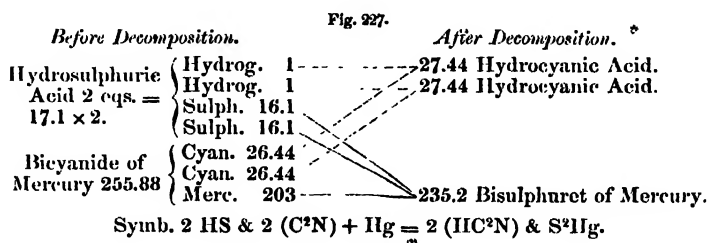
1683. The hydrocyanic acid obtained in this manner is very strong and pure, and equal in weight, when carefully collected, to about a fifth part of the bicyanide employed.

1684. There is another method of preparing this acid in a concentrated state.   Pour nine parts by weight of hydrochloric acid, specific gravity 1.15, on ten of the bicyanide of mercury in a small glass-retort, the beak of which is connected with a receiver or tube in the manner represented in Fig. 226, the tube being filled with fragments of marble and chloride of calcium. A reaction takes place between the bicyanide of mercury and the hydrochloric acid (which is composed of chlorine and hydrogen), exactly similar to what has been illustrated in the preceding diagram with hydrosulphuric acid ; the chlorine, in two equivalents of the acid, combining with the mercury in one equivalent of the bicyanide, and forming bichloride of mercury, while the corresponding equivalents of hydrogen and cyanogen unite and produce two of hydrocyanic acid.   The hydrocyanic acid is always mixed at first with a little water and hydrochloric acid ; the tube in which it condenses should be kept cold.

On removing the retort and closing the extremity of the tube, it passes over into the receiver when a gentle heat is applied, the chloride of calcium retaining the water, and the marble the hydrochloric acid. A slight excess of the bicyanide is employed to prevent as much as possible the escape of any hydrochloric acid. *Symb.* 2HCl & 2 (C^2N) + Hg = 2 (HC^2N) & Cl^2Hg.

1685. Concentrated hydrocyanic acid is speedily decomposed by the reaction of its elements, and a diluted acid is employed for most chemical and all medical purposes. In this state, it may be procured with great facility from the ferrocyanate of potassa. According to the London College the materials employed are used in the following proportions:—

Ferrocyanate of potassa	.	.	.	two ounces.
Aqueous sulphuric acid	.	.	.	one and a half ounces.
Distilled water	.	.	.	a pint and a half.

The acid is mixed with four fluid ounces of the water and allowed to cool; it is then poured upon the ferrocyanate dissolved in half a pint of the water, in a flask with a bent tube, adapted to it by a cork, or in a retort; and eight fluid ounces of the water being put into a receiver, the diluted hydrocyanic acid which escapes on the application of heat is distilled into it, removing the receiver when six fluid ounces have passed into it. To obtain it of the strength required by the College, six more ounces of water are recommended to be then added, or as much as may be sufficient to enable 100 grains to be entirely and accurately decomposed by 12.7 grains of nitrate of silver previously dissolved in distilled water.

1686. In this process a complicated action takes place according to Professor Everitt; the following is the explanation he gives:—The salt employed contains 3 eqs. of cyanogen combined with 2 of potassium, 1 of iron, and 3 of water; and 6 eqs. of the aqueous sulphuric acid decompose 2 of the ferrocyanate, the products being 3 eqs. of bisulphate of potassa, 3 of hydrocyanic acid, and 1 of a yellow salt composed of 1 eq. of cyanide of potassium, 2 of cyanide of iron, and 9 of water, 3 eqs. of which only are decomposed. *Symb.* 2 (3 C^2N + 2 K + Fe) & 3·H & 6·S = 3 (2·S + ·K) & 3 (HC^2N) & C^2NK + 2 (C^2NFe).

The distillation should be conducted slowly with a gentle heat, as that of a sand-bath. Care must be taken to preserve the

receiver cool. The acid prepared in this manner often acquires a bluish tint on being kept, from a small quantity of iron, carried over from the ferrocyanate during distillation, being converted into Prussian blue by reacting on part of the acid ; by distillation it may be obtained colourless.

1687. Another method, which Dr Ure recommends when a concentrated acid is not required is, to pass a stream of hydrosulphuric acid gas through a solution of the bicyanide of mercury till no more sulphuret of mercury is precipitated, and to agitate the hydrocyanic acid which remains in solution with carbonate of lead as long as it is rendered black, to remove the excess of hydrosulphuric acid.* The same reaction takes place that has been already described, and the solution which is obtained is transparent and colourless when properly prepared.

1688. The diluted acid prepared at the Apothecaries' Hall in London is obtained, according to Brande, by distillation from one part of bicyanide of mercury mixed with an equal weight of hydrochloric acid (sp. gr. 1.15) and six parts of water ; continuing the distillation till the liquid condensed is equal to the water employed. Here a slight excess of hydrochloric acid is employed. Perhaps it would be better to employ a slight excess of the bicyanide, to prevent any hydrochloric acid passing over into the receiver.

1689. A very convenient process for preparing hydrocyanic acid for medicinal use, was pointed out by Professor Clarke in the 14th Number of the Glasgow Medical Journal. The following is his formula :—

" Take of

Tartaric acid,	72 grains.
Cyanide of potassium,	32 do.
Distilled water,	an ounce.

In an ounce phial, furnished with a cork or stopper, which should, by previous examination, be ascertained to be sufficient, dissolve the tartaric acid in the water. Then add the cyanide of potassium, and immediately thereafter insert the cork or stopper, which for a little must be preserved firmly in its situation by the finger. Meanwhile agitate, keeping the phial immersed in

* See par. 335, page 109.

a basin of cold water, in order to repress the heat produced in the process. When all action has ceased, set the phial aside in a cool and dark place for twelve hours, in order that the cream of tartar formed may subside. Afterwards decant the liquor, which preserve in a cool and dark place.

" An ounce of water dissolves no more than about 5 grains of cream of tartar, and its soluble power is likely to be diminished by the presence of hydrocyanic acid ; therefore, all the cream of tartar formed, except 5 grains, that is 86 grains, will subside ; and the water will hold in solution, besides these 5 grains of cream of tartar, 13 grains of hydrocyanic acid. But this solution will contain about 26 full doses (we will say 25) of hydrocyanic acid. Of cream of tartar, therefore, each dose will contain only $\frac{5}{25}$, or one-fifth of a grain."

1690. The cyanide of potassium consists of 26.44 parts of cyanogen (one equivalent), and 39.2 of potassium (one equivalent) : it decomposes one equivalent of water, the cyanogen forming hydrocyanic acid with the hydrogen, and the potassium being converted into potassa by combining with the oxygen. Two equivalents of tartaric acid (66.48×2) contained in 150.96 of the crystallized acid, are required to form cream of tartar with the potassa, 27.44 parts (one equivalent) of hydrocyanic acid being then left in solution with a small quantity of the bitartrate. In the above formula, Professor Clarke has omitted some fractions, which he considered too unimportant to be noticed.

1691. The cyanide of potassium is procured from the ferrocyanate of potassa. This salt is regarded as a compound of water, cyanide of potassium, and cyanide of iron ; and by exposing it to a red-heat in an iron-bottle as long as any gas is disengaged, after expelling water by a moderate heat, all the cyanide of iron is decomposed, but none of the cyanide of potassium. Care must be taken to exclude the action of the air, otherwise the cyanide of potassium will also be decomposed. On boiling the residuum with water, and filtering, a solution is obtained, which gives crystals of the cyanide of potassium on evaporation. This salt has also been found by Professor Clarke to be produced as an incidental product at some of the blast furnaces for the preparation of iron ; the minutiæ, connected with its production from this source, have not yet been explained.

1692. Another process for preparing quickly the diluted hydro-

cyanic acid, consists in mixing intimately by agitation in a well stepped phial

> 48 grains of Cyanide of Silver,
> 39½ -   of common Hydrochloric Acid.
> 1 fluid ounce of Distilled Water.

The hydrogen of the hydrochloric acid combines with the cyanogen of the cyanide and remains in solution; chloride of silver is left. The solution is to be decanted, and preserved from the access of light.

Symb. C^2NAg and $HCl = HC^2N$ and $ClAg$.

1693. The cyanide of silver may be procured by adding hydrocyanate of potassa to a solution of the nitrate of silver. It is precipitated immediately, and, after being washed, must be dried cautiously, as it is decomposed rapidly when heated.

1694. Pure and concentrated hydrocyanic acid is a limpid fluid like water, but has a strong and penetrating odour, producing severe headach, with nausea, and even fainting, when the vapour which it emits is incautiously inspired. I have seen a very stout man so much affected by smelling some diluted acid, which had been prepared three months before from the ferrocyanate of potassa, by the process described in 1685, that the bottle containing it fell out of his hand, and for half an hour afterwards he was almost totally unconscious of what was going on around him. It is seldom that the diluted acid affects any one so powerfully, but this shews the great care which should be taken in making any experiments with this substance. A single drop of the strong acid, introduced into the throat of a large dog, kills it after a few hurried inspirations. Its odour is similar to that of the peach blossom, bitter almond, &c., which indeed derive their agreeable flavour from the presence of a small quantity of this acid. The diluted acid may be kept for many months after it has been prepared, if excluded from the light, especially if prepared from the ferrocyanate of potassa by sulphuric acid, when it can be kept for years, probably owing to the presence of a minute quantity of sulphuric acid. But the strong acid is sometimes decomposed in a few hours after it has been made, and can seldom be kept more than a fortnight at ordinary temperatures.

Its taste is cool at first, but it soon becomes hot and irritating. It evaporates rapidly when exposed to the air : if a drop be suspended at the extremity of a small rod, part of it is congealed by the cold produced by the evaporation of the rest. With water and with alcohol it combines in all proportions. It reddens the infusion of litmus faintly, combines with the salifiable bases, for which it has a feeble affinity, but does not neutralize them, and may be displaced even by the carbonic acid.

1695. When hydrocyanic acid is not diluted with much water, it may be obtained in a very concentrated form. if not in a state of absolute purity, by adding cautiously to it chloride of calcium in an extremely minute state of division, and in small successive portions, cooling the phial in which the materials are placed after each addition, by placing it in a freezing mixture. Very cold water will be sufficient if a very small quantity, as half a dram of diluted acid be used. The phial should be long and narrow, and when the reaction is completed, the concentrated acid floats upon the chloride of calcium in solution. If the acid be very dilute, the chloride of calcium does not separate from it. If it be very strong, and chloride of calcium be added quickly and incautiously, the hydrocyanic acid boils with rapidity in consequence of the heat evolved.

1696. The specific gravity of the diluted acid varies according to the quantity of water which is combined with it, and Dr Ure has well remarked that the density of the liquid acid is a criterion of greater nicety than most practitioners will be inclined to appeal to in estimating its strength, diluted acid of the specific gravity 0.998 containing twice as much dry acid as when it is 0.996.

1697. In estimating the strength of hydrocyanic acid, nitrate of silver is almost invariably preferred. Hydrocyanic acid decomposes it and precipitates cyanide of silver, while water is formed by the union of the hydrogen of the acid with the oxygen of the oxide. The nitric acid remains in solution.

Symb. HC²N & ::N·Ag = C²NAg & ·H & ::N.

The cyanide of silver is then washed repeatedly with water, till the water does not affect hydrochloric acid, proving thereby that all excess of nitrate of silver has been removed, and after drying it, it is introduced into a glass-tube, previously weighed carefully, and heated till the cyanogen is expelled, and metallic

silver is left.   The increase of weight in the tube indicates the quantity of silver left, and every 108.3 grs. (one eq.) indicate 26.44 grs. of cyanogen (one eq.), which must have been supplied by 27.44 grs. of hydrocyanic acid (one eq.).   With a good balance, 10 or 20 grs. of the acid will be sufficient if it be of moderate strength.

1698. If any hydrochloric acid be mixed with the hydrocyanic acid, it may be detected by adding ammonia till the liquid is neutralized, and evaporating it to dryness by a heat not exceeding 212°.   Both acids combine with the ammonia, and the hydrocyanate is dissipated, but the hydrochlorate remains, requiring a temperature of 360° for its volatilization.   Nitrate of silver cannot be employed in this instance, though the most delicate test of hydrochloric acid, as the hydrocyanic acid gives a precipitate with a solution of this salt, which it is not easy to distinguish at first from that produced by hydrochloric acid, when they are mingled together.   But by nitric acid subsequently applied, the cyanide of silver may be dissolved, whereas chloride of silver is insoluble in this acid.

1699. When hydrocyanic acid has been administered in an over-dose, or given as a poison, the best and indeed the only antidote, according to Dr Herbst, is the cold affusion.   He made a number of experiments on animals, and states that when the dose of the poison was not sufficient to prove fatal, two affusions of cold water in general removed every unpleasant symptom ; when a large dose was given, it was found necessary to repeat it more frequently, and to persevere for a considerable time. The certainty of success depends much on the early employment of the remedy.   He tried liquid ammonia repeatedly, which has been much extolled as an antidote to this poison, but says that it will scarcely ever save life, where a dose sufficient to prove fatal has been given, and the symptoms have continued for some time ; though he admits, that where the quantity administered is not able to destroy life, it is of great benefit in mitigating the severity of the symptoms.   Another evident objection to the use of ammonia, as Dr Herbst remarks, is, that it excoriates the parts to which it is applied, and when sufficiently diluted to be free from this inconvenience, it is of very little use.   The cold water was poured freely over the head and back, and afterwards over the whole body.   Chlorine water, or a solution of

the chloride of lime, has been much recommended, immediately decomposing hydrocyanic acid.

1700. Hydrocyanic acid for medicinal purposes is employed of very various degrees of strength. The diluted acid of the London College contains 2 per cent. of dry acid.

1701. The tests proposed for detecting hydrocyanic acid are the nitrate of silver, the sulphate of copper, and the sulphate of iron.

1702. Drop a solution of the nitrate of silver into a little diluted hydrocyanic acid; a white curdy precipitate (cyanide of silver) falls, which cannot be easily distinguished from the precipitate that hydrochloric acid, or common salt, gives with the same solution. This test, therefore, is not much resorted to, at least where the quantity of material to be operated upon is very small, though it is very sensible in its indications as to the amount that may be present in any solution known to contain the acid.

1703. Add a few drops of a solution of the sulphate of copper to the hydrocyanic acid, and then a slight excess of caustic potassa, also in solution. The potassa separates the oxide of copper in the form of a blue precipitate which reacts on the hydrocyanic acid, the oxygen of the oxide combining with the hydrogen of the acid, while the cyanogen unites with the copper. The compound of cyanogen and copper is recognised by its white colour after hydrochloric acid has been added to remove the excess of copper thrown down by the potassa.

1704. The sulphate of iron is employed precisely in the same manner as the sulphate of copper. It is not necessary that the sulphate should contain no persulphate of iron (which it generally does), but the persulphate of iron alone should not be used, as Dr Turner has observed, the hydrocyanic acid having little or no action upon the peroxide of iron precipitated from it by potassa, while, with the sulphate, the oxide is precipitated, a small portion of which at least must be present, in order that the characteristic colour of Prussian blue may be speedily developed by the pure acid. Dr Ure states, that this acid may be detected by the sulphate of iron when mixed with 10,000 parts of water, and that the sulphate of copper produces a slight milkiness in water containing only a 20,000th part.

1705. A great variety of statements have been made as to

the changes that ensue in the production of Prussian blue, by the action of hydrocyanic acid and the oxide of iron. It appears now to be admitted,

I. That one eq. of oxide of iron decomposes one of hydrocyanic acid, forming cyanide of iron and water.

II. That the cyanide of iron so formed combines with two eqs. of undecomposed hydrocyanic acid, producing ferrocyanic acid.

III. That the ferrocyanic acid so produced combines with peroxide of iron and forms Prussian blue.

1706. According to MM. Leuret and Lassaigne, two or three days after death it is impossible to detect this poison, as it is soon decomposed or volatilized. When it is suspected that death has been occasioned by it, they recommend the intestines to be cut into small pieces, and put into a retort with their contents and some water, adding a small quantity of sulphuric acid and applying a gentle heat, which should not exceed 212°. The volatile products are to be condensed in a receiver kept cold with ice, and tested in the manner described above. The odour alone is often sufficient to indicate its presence.

CYANIC ACID.

Symb. C^2N.   *Eq.* $34.44 = O.8 + C.12.24 + N.14.2.$

1707. To prepare cyanic acid, heat equal weights of ferrocyanate of potassa and binoxide of manganese to dull redness in a silver crucible ; cyanate of potassa is thus formed, which is separated by solution in alcohol and subsequent crystallization. Dissolve the cyanate in water and decompose it by nitrate of silver ; cyanate of silver is precipitated, and nitrate of potassa remains in solution. Let hydrosulphuric acid gas now be passed through water in which the precipitated cyanate of silver is suspended ; sulphuret of silver and water are thus formed, and, the cyanic acid remains in solution. Less hydrosulphuric acid should be employed than is necessary to decompose the whole of the cyanate.

1708. Cyanic acid is decomposed with extreme facility

especially by water, which resolves it into the bicarbonate of ammonia.

$$Symb.\ 3 \cdot H\ \&\ \cdot C^2N = 2\ :C + NH^3.$$

1709. The FULMINIC ACID, produced by the action of alcohol with a solution of silver or mercury in an excess of nitric acid, is considered isomeric with cyanic acid, but its equivalent has been regarded as double that of the cyanic acid, being $O^2 + 2\ (C^2N)$. It has been examined more particularly by Professor Davy, and by Liebig and Gay Lussac, whose analyses, however, do not correspond.

1710. Prepared according to Professor Davy, by mixing one part of the fulminate of mercury with 2 of zinc and 18 of water. Fulminate of zinc is procured, from which the oxide of zinc is removed by baryta, and sulphuric acid separates the baryta. It is liquid, volatile, poisonous, has an odour like hydrocyanic acid, and is easily decomposed.

FERROCYANIC ACID. (FERROPRUSSIC ACID—HYDRO-FERROCYANIC ACID.)

$$Symb.\ 3\ (C^2N) + 2\ H + Fe.\quad Eq.\ 109.32 = C.36.72 + N.42.6 + H.2 + Fe.28.$$
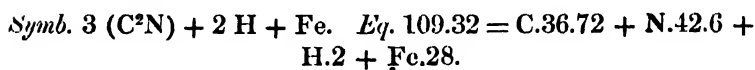
1711. When dry animal matters mixed with half their weight of the carbonate of potassa and metallic iron are exposed for half an hour to a dull red-heat in an iron pot covered with a lid, having a small aperture to allow vapours to escape, a peculiar compound is formed, which may be separated from the other materials by water, and the solution gives large yellow-coloured crystals. They are composed of what is commonly termed the ferroprussiate or ferrocyanate of potassa; and it is this salt that is used to prepare the different substances from which cyanogen and its other compounds are usually obtained. Nitre has been recommended instead of carbonate of potassa for mixing with the animal matters when they are first subjected to heat.

1712. The process for preparing it is very offensive, but on the small scale, a sufficient quantity may be formed from an ounce or two of materials, to shew the nature of the salt obtained in solution when the dry mass is digested in water and

filtered. The minutiæ of the reaction that takes place in the first stage of the process are still far from having been completely explained. The animal matter, which is composed of carbon, oxygen, hydrogen, and nitrogen, is completely decomposed, part of the nitrogen and carbon combining and forming cyanogen, which combines with iron and potassium ; and on extracting the soluble compound in water, and concentrating the solution, crystals are formed, composed of 3 eqs. of water, 2 of cyanide of potassium, and 1 of cyanide of iron.

1713. There are two processes for procuring this acid from the ferrocyanate of potassa. One consists in adding a solution of 58 parts of crystallized tartaric acid dissolved in alcohol to 50 of the ferrocyanate dissolved in as small a quantity of water as possible. The tartaric acid combines with the potassa of the ferrocyanate, forming bitartrate of potassa, which is precipitated in small crystals, not being very soluble in water, and the ferrocyanic acid which remains in solution may be separated from it by filtration. A small portion of the bitartrate remains in solution with the acid.

1714. In the other process, a solution of the hydrosulphate of baryta is added to a solution of the ferrocyanate of potassa, as long as any precipitation takes place, hydrosulphate of potassa remaining in solution, while ferrocyanate of baryta is precipitated. It is washed on a filter with a small quantity of cold water, then dissolved in 100 parts of this fluid, and by adding sulphuric acid as long as any baryta is precipitated, taking care to avoid any excess, the ferrocyanic acid is obtained in solution.

1715. This acid may be obtained in small cubic crystals of a yellow colour, by allowing its solution to evaporate spontaneously. It reddens the vegetable blues, and has a much greater affinity for the different salifiable bases than hydrocyanic acid, neutralizing them completely. It is not volatile, and is slowly decomposed when exposed to the light, the iron which it contains acquiring oxygen, and being ultimately converted into Prussian blue. It is not poisonous, at least in small doses. Many are inclined to doubt if this compound ought to be considered as a distinct acid, and have considered it as a compound of the cyanide of iron with hydrocyanic acid. On decomposing the ferrocyanate of potassa by the galvanic power, the iron ac-

companies the other elements that are associated with it in the acid to the positive pole, where acids are attracted on decomposing salts by galvanism, and does not go along with the other salifiable bases to the negative pole, where metallic oxides are always found when they have been separated by its agency from acids with which they have been combined, and where the iron ought to have been disengaged, if it had been in combination with the hydrocyanic acid, in the same manner as when potassa or any other base is united with an acid in a compound salt. It was called at first ferrureted *chyazic* acid, from the initial letters of carbon, hydrogen, and azote (nitrogen), but ferrocyanic acid is the term that is now adopted. The annexed diagram illustrates the manner in which the cyanogen, iron, and hydrogen, are arranged, when the compound is viewed as a bihydrocyanate of the cyanide of iron.

Fig. 228.

Hydrogen   1 - - ------- 27.44 of Hydrocyanic Acid.
Hydrogen   1 - - ----- 27.44 of Hydrocyanic Acid.
Iron ...   28
Cyanogen 26.44
Cyanogen 26.44
Cyanogen 26.44   - - 54.44 of Cyanide of Iron.

1716. The most important compound of this acid is the FERRO-CYANATE of POTASSA, used principally for the preparation of Prussian blue, but employed also in preparing hydrocyanic acid, cyanide of potassium, hydrosulphocyanic acid, and in testing metals in solution.   With a salt of the protoxide of iron, it gives a white precipitate, which quickly passes to a blue if exposed to the air ; but with a persalt of iron, a deep blue tint is produced the moment they come in contact.   It ought particularly to be recollected in using this salt as a test of iron, that if it be mingled with an acid solution, it is frequently decomposed, and Prussian blue produced by the reaction of its elements, even though no iron be contained in the liquid under examination.

1717. The RED FERROCYANATE of POTASSA is procured by the action of chlorine gas upon the ferrocyanate of potassa dissolved in water, the chlorine being transmitted through the liquid till it ceases to give a precipitate with the persalts of iron ; the solution may then be concentrated and crystals procured by evaporation.   The solution is of a blood-red colour by transmitted

light, but green by reflected light, and is particularly distinguished by precipitating of a deep blue (or greenish) tint the protosalts of iron. Its precise composition has not been definitively determined ; Gmelin regarded it as a compound of 3 eqs. of potassium, 2 of iron, and 6 of cyanogen, but according to Johnson, it may be considered as a compound of 4 eqs. of cyanide of potassium, 2 of cyanide of iron, and 1 of chlorine.

1718. Perferrocyanate of Iron or Prussian Blue is usually regarded as a compound of ferrocyanic acid and peroxide of iron, but very different statements have been made as to the manner in which its elements are associated. It is formed when a solution of the ferrocyanate of potassa is mingled with a solution of a persalt of iron. Common Prussian blue contains much alumina, which may be removed by digesting it in water acidulated with hydrochloric acid. A small portion of cyanide of potassium is also generally found in combination with this substance as at first prepared, in consequence of which it must be washed with acidulated water, otherwise a portion of the Prussian blue is dissolved in the solution of the cyanide of potassium.

Hydrosulphocyanic Acid (Sulphocyanic Acid).

Symb. HS^2C^2N. *Eq.* $59.64 = H.1 + S.32.2 + C.12.24 + N.14.2$.

1719. This acid is obtained in combination with water by adding sulphuric acid to a solution of the hydrosulphocyanate of potassa, and distilling the liquid in a glass-retort. The solution of the hydrosulphocyanate is prepared by a process introduced by Grotthus. Equal weights of the ferrocyanate of potassa and sulphur, both previously reduced to fine powder, are intimately mixed and exposed to a considerable heat in a common crucible, taking care, however, not to allow it to become red-hot. The mixture soon melts and takes fire, and must be withdrawn from the chauffer a few minutes after the combustion ceases. In this process part of the sulphur combines with the cyanogen of the ferrocyanate, forming a peculiar compound termed sulphocyanogen, or, more properly, bisulphuret of cyanogen, which unites with the potassium, forming sulphocyanide of potassium ; an-

other portion of sulphur combines with the iron of the ferro-cyanate, forming sulphuret of iron. The hydrosulphocyanate of potassa is procured in solution by digesting this residuum in wa-ter, the potassium combining with the oxygen of a portion of water which is decomposed. while the hydrogen goes to the sul-phocyanogen, forming hydrosulphocyanic acid. By filtration, it is separated from the sulphuret of iron and any sulphur that may have remained mixed with it. This solution is then to be distilled with a quantity of sulphuric acid, equal to about half of the weight of the ferrocyanate of potassa mixed with the sul-phur. Sulphate of potassa remains in the retort with a little hydrosulphocyanate of potassa, and the hydrosulphocyanic acid and water are condensed in the receiver.

1720. When its solution in water is concentrated, it boils at 216°, and crystallizes at 54° in six-sided prisms. It reddens the vegetable blues, neutralizes the alkalis, and forms a soluble salt of a deep red colour with the peroxide of iron. A single drop of a diluted solution of this acid, added to a very dilute so-lution of a persalt of iron, will immediately produce the charac-teristic tint. When boiled with iron-filings, sulphuret of iron is formed, and hydrocyanic acid disengaged.

CYANIDES OF CHLORINE, IODINE, AND BROMINE.

1721. When chlorine is transmitted through diluted hydro-cyanic acid till it has acquired the property of decolorizing a solution of indigo in sulphuric acid, one portion of the chlorine combines with the cyanogen of the acid, forming cyanide of chlorine, and another with the hydrogen, forming hydrochloric acid. The excess of chlorine may be removed by agitating the liquid with mercury, and on exposing it to heat, the cyanide of chlorine is disengaged in the gaseous form, and must be col-lected over the mercurial trough, as it is soluble in water. It is always mixed with carbonic acid, when prepared in this man-ner, formed by the combination of the oxygen of a portion of the water with the carbon of part of the cyanogen which is de-composed. Another process for procuring this substance is de-scribed by M. Serullas, in the Ann. de Ch. et Phys. vol. xxxv.; and in the preceding and subsequent volumes of the same work,

there are several interesting memoirs on this subject, where he has described a bichloride of cyanogen.

1722. Cyanide of chlorine was formerly termed chlorocyanic acid, but it was found to possess no acid properties on more minute examination. It has a very pungent and irritating smell, and is absorbed rapidly by solutions of the alkalis, alcohol, and water. When cooled by a freezing mixture, it becomes liquid at 10', and freezes at zero.

1723. Cyanide of Iodine is prepared by exposing the bicyanide of mercury mixed intimately with half its weight of iodine to heat in a small glass-retort ; vapours of iodine are disengaged at first, and these are soon followed by white fumes of the cyanide of iodine, having the appearance of wool, which may be condensed in a cold receiver in the solid form.

1724. Cyanide of Bromine is prepared by a similar process, and bears a great resemblance to the cyanide of iodine. It appears to be as powerful a poison as the hydrocyanic acid.

1725. Numerous other combinations of cyanogen, or of compounds produced by its decomposition, have been lately described, as Bisulphuret of Cyanogen, Disulphuret of Cyanogen, Mellon, Melam, Melamine, Ammeline, Ammelide, Cyanamide ; also a number of double salts containing cyanogen in combination with two metals, but the compounds already noticed are the most important.

ORDER II.—VEGETABLE ALKALIS.

1726. The most important of the vegetable alkalis are Morphia, Quina, Cinchonia, Strychnia, and Veratria ; the method of preparing these from the different vegetable products from which they are obtained, will be described in the following sections.

1727. These alkalis are found in combination with vegetable acids, constituting a peculiar class of salts. By digesting them in water or alcohol these salts are dissolved, and on adding one

of the common alkalis, or an earth, such as lime or magnesia, the vegetable alkali is separated, the salifiable base added combining with the acid. Various modifications of this process are adopted in the preparation of the different alkalis, but they are not obtained in a pure form by any single operation, being usually combined with a considerable quantity of colouring matter and other proximate principles. Animal charcoal is employed to separate or decompose the colouring matter. Ether and alcohol may often be used with advantage. By repeatedly dissolving them and precipitating or crystallizing them from their solutions, the separation of the colouring matter may sometimes be effected without any charcoal, but it is in general preferable to employ this substance.

1728. Dr Thomson states, that " it has been found that all the vegetable alkalis are precipitated by tannin or infusion of nutgalls, but not by gallic acid, the precipitate containing, according to M. Henry, two eqs. of tannin and one of alkali." The infusion of nutgalls has accordingly been proposed by M. Henry as a reagent for procuring these alkalis in an insulated form, according to the following process :—" Digest the plant containing the alkali in warm water, acidulated with sulphuric acid. Draw off the clear liquid, neutralize it by potash, and add a concentrated infusion of nutgalls as long as a precipitate falls. Separate the precipitate, wash it with cold water, and mix it intimately with a slight excess of slaked lime. Dry the mixture over the vapour-bath till it is reduced to powder ; digest this powder in alcohol or ether ; filter, distil off the alcohol or ether ; set the residue aside for some days ; the alkali will be deposited in crystals."—*Thomson's Organic Chemistry.*

1729. M. Pelletier, in a paper on the action of iodine upon different salifiable bases, has been led to the following conclusions :—

" That iodine combines with most of the organic bases in atomic proportion. Thus, strychnia affords a crystalline and coloured iodide, composed of two eqs. of iodine and one eq. of strychnia ; brucia forms two iodides, one composed of two eqs. of iodine and one eq. of brucia, the other of four of iodine to one of base ; whilst cinchonia and quina each combine with iodine in the proportion of one eq. of iodine to one of base.

" That iodic acid combines with the organic bases, forming

neutral and acid salts, in which the acid and base exist in the same proportion as in their respective iodides.

" That hydriodic acid unites with the organic bases, forming salts which have a tendency to an excess of base. The organic hydriodates are decomposed by iodic acid, iodine being liberated, whilst the hydriodate is converted into an iodide.

" The action of iodine upon morphia forms a very singular exception to the above, for one part of the iodine combines with hydrogen from the morphia to form hydriodic acid, whilst the other portion of iodine unites with the substance resulting from the morphia. When morphia is acted on by iodic acid, the acid loses its oxygen, which unites with one portion of the morphia, forming a red substance like that resulting from the action of nitric acid on morphia, whilst the iodine evolved acts on the other portion of morphia as it does by direct contact ; but the resulting combination is decomposed by a fresh portion of iodic acid, and entirely converted into iodine and the red substance.

" The following singular reaction, in the opinion of M. Pelletier, throws great light on the theory of organic iodides : When a solution of a neutral iodate of strychnia is poured into a solution of a hydriodate of the same base, no apparent decomposition takes place : but, if iodic acid or an acidulous iodate be substituted for a neutral one, a brown precipitate is obtained, formed of iodide of strychnia and free iodine. When this precipitate is macerated in a solution of bicarbonate of potash, the excess of iodine dissolves, and the iodine then assumes the orange-yellow colour which belongs to it, and it then resists the action of the bicarbonate.

" In this decomposition, the five equivalents of hydrogen of the hydriodic acid of the five equivalents of hydriodate of strychnia combine with five equivalents of oxygen of the iodic acid to form water, and the five equivalents of strychnia are precipitated with six equivalents of iodine, one of which is dissolved by the bicarbonate of potash, and five equivalents of neutral iodide of strychnia remain."—*Philosophical Magazine and Annals.*

SECT. I.—MORPHIA—MECONIC ACID—CODEIA, THEBAIA,
NARCEIA, MECONINE, NARCOTINE.

1730. Opium is composed essentially of a peculiar vegetable
alkali which has received the name of Morphia, a vegetable
acid which has been called Meconic Acid, and some other ve-
getable proximate principles which are present in much smaller
quantity. . These are mixed in opium with several more com-
mon vegetable principles, as gum, resin, gluten, a bitter matter,
a dark colouring matter, and also with a small quantity of sul-
phate of lime.

1731. MORPHIA. *Symb.* $O^6C^{34}H^{18}N$. *Eq.* $288.28 = O.48 +$
$C.208.08 + H.18 + N.14.2.$ A number of processes have been
proposed for extracting morphia from opium ; the beginner will
perhaps find the following process of Robiquet's more easily
conducted than any other.

1732. Take 1200 grains of the best Turkey opium, cut it into
small pieces, and rub it with water in a mortar, adding a little
more from time to time till a uniform pulpy mass is obtained.
Then add more water till about ten ounces altogether shall
have been mixed with the opium.   The mixture is to be left in
this state for five days, shaking it occasionally ; or it may be di-
gested with a gentle heat for a day or two, taking care not to
raise its temperature above 100°, after which it may be filtered.
An additional supply of water may then be used, and on the
large scale, water is added and decanted after the opium has
been macerated in it, till it ceases to extract any thing further
from the residuum.   The liquid that passes through the filter
has a very dark colour, and contains 'the meconic acid and the
morphia in solution, combined together in the form of meco-
nate of morphia.   On boiling this solution for ten or twelve mi-
nutes with 60 grains of magnesia, taking care to have it com-
pletely decarbonated, this earth withdraws the meconic acid,
and the morphia is precipitated.

1733. Put the precipitate on a filter, wash it with cold water,
and allow it to drain.   When dry, mix it with a third of its
weight of animal charcoal, and boil it with about two ounces
of alcohol in a glass-flask for five or ten minutes.   The alcohol

dissolves the morphia, separating it from the other matters with which it is associated in the precipitate. It must be filtered while hot through paper; the morphia is deposited in crystals as the solution cools. It is only by repeated solution and crystallization, however, that the morphia is obtained perfectly pure; the product of the first crystallization has a light fawn colour when a sufficient quantity of animal charcoal has been employed, and is usually associated with small portions of some of the other vegetable alkalis found in opium, especially codeia.

1734. In preparing morphia, the student should always avoid the vapours that are disengaged from the different solutions which he may require to boil, when he is operating on a considerable quantity of materials, as I have occasionally seen them produce the same effects as an overdose of opium, where this has not been attended to. On the other hand, numerous individuals are not in any way affected by them, and those practically engaged in preparing morphia or its combinations on the large scale, have not, so far as I am aware, complained of any injurious consequences arising from them.

1735. According to the process of the London College, morphia is prepared by the action of ammonia upon a solution of the hydrochlorate of morphia, hydrochlorate of ammonia remaining in solution, while the morphia is precipitated. An excess of ammonia must be avoided, as it is apt to redissolve part of the precipitate.

1736. Morphia is the vegetable principle on which the narcotic property of opium more immediately depends, and its taste is intensely bitter. From its sparing solubility in water, it produces comparatively little effect upon the animal economy in its pure form, but when combined with an acid or any other substance which can render it soluble, or when it meets with any solvent in the contents of the stomach, it acts with great energy, half a grain given to a man in good health having produced symptoms which excited considerable alarm at the time, though he ultimately recovered.

1737. Put a test-paper coloured by the blue infusion of cabbage into a solution of morphia in alcohol; it will be immediately rendered green.

1738. Put another test-paper coloured yellow by turmeric into the same solution; it will be turned to a reddish-brown.

1739. Add a solution of potassa, soda, or ammonia to a solution of a salt of morphia ; the alkali will combine with the acid, and the morphia will be precipitated.   Morphia is precipitated also when a solution of any of these alkalis is added to a watery infusion of opium, a meconate of the alkali remaining in solution.   With the exception of ammonia, however, none of them can be used so advantageously for the preparation of morphia as magnesia, as any excess would react on other matters in solution, and tend to decompose them, or dissolve the precipitated morphia.

1740. Morphia and its combinations, unless purified by many successive solutions and crystallizations, and also by the action of animal charcoal, appear frequently to be associated with a little resin, to which some attribute the colour it produces with nitric acid in the following experiments.

1741. Put a small quantity of morphia into a test-tube, and pour a little nitric acid on it.   The solution soon acquires a yellowish tint which passes quickly to a blood-red and ultimately becomes yellow again.   The deep red tint arises from the evolution of nitrous acid fumes which soon escape.   A portion of oxalic acid is ultimately formed by heating the materials.

1742. Pour some nitric acid into a solution of the sulphate of morphia, or of any other salt of this substance ; the solution will acquire the same deep colour as in the preceding experiment (1741).   The deep red tint which morphia and its compounds produce with nitric acid was, till lately, considered a characteristic property of this vegetable alkali ; it has now been found, however, that strychnia produces the same effect: A small portion of resin, it must also be remembered, and other deoxidating agents, communicate a deep red tint to nitric acid.

1743. If a solution of morphia or of any of its salts be mixed with a strong solution of chlorine, and ammonia be added, a dark brown colour will pervade the solution, which will disappear by the addition of more of the solution of chlorine.   It is particularly necessary for the success of these reactions that the chlorine and ammonia water be strong.   (Dr Meeson.)

1744. Add a small quantity of a solution of potassa to a solution of the sulphate of morphia ; the sulphuric acid will combine with the potassa, and the morphia will be precipitated.

1745. Pour some more of the solution of potassa into the

above liquid, and the morphia will be redissolved.   Similar experiments may be made with solutions of soda and ammonia.

1746. Expose a little morphia to heat in a test-tube over a spirit-lamp ; in a short time it will be completely decomposed, some carbonate of ammonia being disengaged along with the other products of the decomposition, as morphia contains a little nitrogen besides the usual elements of vegetable matter : the ammonia is formed by the combination of nitrogen with part of the hydrogen, and the carbonic acid by the union of part of the carbon and oxygen.   A little oily matter is also produced, and some carbonaceous matter is left in the tube.

1747. Throw some morphia on a piece of iron heated to redness, or on some red-hot cinders : it burns in the same manner as other vegetable substances.

1748. Shake some morphia with a small quantity of diluted sulphuric acid, heat the mixture gently, and continue to add morphia till it is no longer dissolved.   The sulphuric acid will be completely neutralized, and a solution of the SULPHATE of MORPHIA will be obtained.   It is very soluble in water.

1749. ACETATE OF MORPHIA is procured according to the process of the London College, by neutralizing morphia with diluted acetic acid.   It has also been obtained by the double decomposition of salts of morphia and soluble acetates, the acetate of morphia remaining in solution, while the base of the acetate used in preparing it is thrown down, in combination with the acid previously combined with the morphia.

1750. The other salts of this vegetable alkali may be prepared by a similar process.   The mineral acids must always be diluted with water before combining them with morphia, as. in their concentrated form, they are very apt to decompose it.

1751. The NITRATE, SULPHATE, HYDROCHLORATE, ACETATE, TARTRATE, and MECONATE of MORPHIA are all soluble and crystallizable.

1752. The HYDROCHLORATE (Muriate) of MORPHIA has been recommended by Dr Gregory as an economical preparation of opium, and has been advantageously substituted for the more common preparations of this medicine.   The following is the process adopted for its preparation, modified by Dr Robertson, and subsequently by Dr Gregory and M. Robiquet.   Evaporate the watery solution of opium in a tinned iron pan till it

attains the consistence of a syrup. Add a strong neutral solution of hydrochlorate of lime, purified carefully from iron. The hydrochlorate should be in excess, so as effectually to secure the decomposition of all the meconate of morphia. Boil for a few minutes, and set it aside ; meconate of lime is deposited along with colouring matter and other impurities. The solution of hydrochlorate of morphia is then separated, and concentrated on the sand-bath till a second deposition ensues, when it is permitted to cool and give crystals, continually agitating it. By subjecting the imperfect crystalline mass procured in this manner to a great pressure, after placing it in a very strong cloth, a dark-coloured liquid is separated, which contains much colouring matter and impurities, and a little hydrochlorate of morphia. By repeated solution and crystallization the crystals of the hydrochlorate are at last obtained in a pure form, any excess of acid being neutralized by carbonate of lime, and animal charcoal being mingled with the solution, and allowed to remain in contact with it at a temperature of about 200° for twelve or twenty-four hours. About one part of hydrochlorate of morphia is procured from ten of opium.

1753. According to the process adopted by the London College, the watery solution of opium, containing the meconate of morphia, is decomposed by the hydrochlorate of lead in solution, meconate of lead falling down, and hydrochlorate of morphia remaining in solution. The morphia is then precipitated by ammonia, washed, and again converted into hydrochlorate by adding hydrochloric acid diluted with water. Charcoal is employed in the usual manner to destroy colouring matter.

1754. The hydrochlorate of morphia crystallizes in a very beautiful manner, resembling feathers, the individual fibres often extending one or two inches in length, as in the specimens manufactured by Mr Macfarlane of this city. It is soluble in about twenty parts of cold water, and in less than an equal weight of water at 212°.

1755. The hydrochlorate of codeia is generally present in small quantity in the hydrochlorate of morphia, where care has not been taken to separate it. See par. 1766.

MECONIC ACID. *Symb.* $O^7C^7H^2$. *Eq.* 100.84.

1756. Several processes have been pointed out for the preparation of Meconic Acid ; the following method, by which it is easily obtained, was recommended by Dr Hare. Add a solution of the ditacetate of lead to a watery infusion of opium as long as any precipitation takes place, wash the precipitate on a filter till the water passes through colourless, then diffuse it through a quantity of water, and pass a brisk stream of hydrosulphuric acid through it for a quarter of an hour or twenty minutes. The precipitate that is thrown down by the ditacetate of lead is composed principally of meconate of lead, which is decomposed afterwards by the hydrosulphuric acid gas, sulphuret of lead and water being formed, while the meconic acid that is disengaged remains in solution. The sulphuret of lead must be separated by filtration, when the solution will appear of a reddish-amber colour. It affords crystals on expelling the excess of hydrosulphuric acid, and concentrating it by evaporation.

1757. The meconic acid may be separated from the meconate of lead by sulphuric acid ; the sulphate of lead that is formed being insoluble, it may be easily separated by filtration from the meconic acid that remains in solution as before. An excess of sulphuric acid interferes with the crystallization of the meconic acid, which is not then obtained so easily in crystals, as when the decomposition of the meconate has been effected by hydrosulphuric acid.

1758. From the precipitated meconate of lime, which is formed in the preparation of hydrochlorate of morphia by hydrochlorate of lime, the meconic acid may be separated by hydrochloric acid, which is added in the first place in sufficient quantity to dissolve the meconate. Bimeconate of lime is deposited in crystals, and from these, dissolved in water, the meconic acid is procured by the action of more hydrochloric acid.

1759. Meconic acid is soluble in water, in ether, and in alcohol ; it has a sour taste, reddens litmus paper, and is particularly distinguished by the dark red colour which it produces when added to a solution of a persalt of iron. Drop a small quantity of the watery solution of meconic acid into a glass of water containing a little of the hydrochlorate or sulphate of the peroxide

of iron. The deep colour which it causes will immediately appear, and so delicate a test is a persalt of iron of the presence of meconic acid, that Dr Hare was enabled to detect the presence of meconic acid by means of it in a gallon of water to which no more than ten drops of laudanum had been added : the following is the manner in which he proceeded. A few drops of a solution of the acetate of lead were added to the water containing the laudanum, which was placed in a conical glass vessel, that the precipitate, which appeared in several hours. and was deposited on the sides of the vessel, might be easily collected at the bottom, by stirring it gently from time to time with a glass-rod. The most of the supernatant liquid was then decanted, or removed by a syphon, taking care that none of the precipitate was drawn up along with it ; after which thirty drops of sulphuric acid were poured over the meconate by means of a dropping-tube, and an equal quantity of a solution of the persulphate of iron was added in the same manner, when the characteristic deep red colour appeared.

1760. Add a small quantity of a solution of the hydrosulphocyanate of potassa to a wine-glass of water, into which a drop of a solution of the persulphate of iron has been put, and compare the colour (1018) with that produced by the meconic acid. which is very similar to it.

1761. Meconic acid crystallizes in thin transparent scales. and gives oxalic acid when digested with nitric acid. When boiled in water for some time, or when a solution of the meconate of potassa acidulated with hydrochloric acid is treated in the same way, a new acid is produced, the METAMECONIC ACID $(Symb.\ O^{10}C^{12}H^{1})$. It is not so soluble as the meconic, and gives hard and granular crystals. During its production, two eqs. of meconic acid lose two of carbonic acid, and produce one of metameconic acid.

$$Symb.\ 2\ (O^{7}C^{7}H^{2}) = 2:C\ \&\ O^{10}C^{12}H^{1}.$$
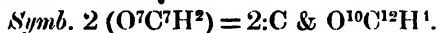
1762. PYROMECONIC ACID is obtained when the meconic acid is exposed to heat $(Symb.\ O^{5}C^{10}H^{3})$, two eqs. of meconic acid losing one of water and four of carbonic acid, as they produce one of the pyromeconic acid.

$$Symb.\ 2\ (O^{7}C^{7}H^{2}) = 4:C\ \&\ \cdot H\ \&\ O^{5}C^{10}H^{3}.$$
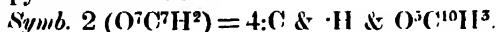
NARCOTINE.

Symb. $O^{12}C^{10}H^{20}N$?

1763. NARCOTINE, another vegetable alkali, known also by the name of the *Salt of Derosne*, from Derosne, who considered that it was meconate of morphia, may be prepared by macerating opium with six or seven times its weight of sulphuric ether, agitating it occasionally, and applying a very gentle heat. The ether employed for this purpose should be extremely pure. The meconate of morphia is not affected by ether, but the narcotine is dissolved, and the solution deposits it in crystals by spontaneous evaporation. By removing the crystals that are at first deposited from any resinous matter that may be mixed with them, and repeated solution and crystallization with ether, boiling also with animal charcoal, they may be obtained perfectly pure.

1764. Narcotine is soluble in alcohol, ether, and oils, but insoluble in water ; the addition of a small quantity of acid, however, renders it soluble, and in the watery infusion of opium it is supposed to be retained in solution by the meconic or some other vegetable acid.

1765. As the unpleasant sensations which the exhibition of opium so often produces, independent of its narcotic action, have of late been attributed to the narcotine alone, it may be deprived of this principle before it is made into laudanum, by digesting it in ether for several hours.

1766. CODEIA (*Symb.* $O^5C^{32}H^{19}N$. *Eq.* 269.04). This substance has hitherto been less minutely examined than morphia and its compounds. It is frequently associated with the common hydrochlorate of morphia, from which it may be separated by dissolving it in water and adding ammonia, when the morphia is precipitated, the codeia remaining in solution. The solution is concentrated and crystals procured, and on dissolving the crystals and adding a solution of potassa, the codeia is precipitated in combination with water. By boiling it in ether, and allowing the solution to evaporate spontaneously, the codeia is deposited in crystals. According to Dr Gregory, the nitrate of codeia, in a dose of 4 or 6 grains, produces intoxication, which, in the

course of a few hours, is succeeded by depression, nausea, and occasionally by vomiting.

1767. NARCEIA (*Symb.* $O^{12}C^{28}H^{20}N$. *Eq.* 301.56). This alkali is prepared by a very complicated process, of which the following is an outline.

1. Evaporate the watery solution of opium till an extract is procured.

2. Dissolve in boiling water and filter.

3. Heat the solution thus procured to the boiling point, and add ammonia in slight excess. Allow the liquid to cool, so that morphia may be separated. Concentrate when cold, that more morphia may be deposited.

4. Add barytic water; the meconic acid is now separated as meconate of baryta.

5. Filter, and add carbonate of ammonia, that any excess of baryta may be precipitated.

6. Filter again, and boil to expel any excess of carbonate of ammonia, evaporating till the liquid assumes the consistence of a thick syrup; a pulpy matter is obtained in a few days in which crystals may be observed.

7. Dry it and boil it in alcohol, after expressing any dark fluid by compressing it strongly in cloth.

8. Filter, and distil off the alcohol; a liquid is left containing narceia, which crystallizes as it cools.

9. Digest it in ether that meconin may be separated.

1768. Narceia crystallizes in very delicate white prisms, having a considerable lustre. It melts at a temperature near 200°, and is sparingly soluble in boiling water. At a higher temperature it is decomposed, giving out white and subsequently yellow fumes, much charcoal being left. A fine blue colour is developed by the action of hydrochloric acid diluted with water upon this alkali, changing subsequently to violet and red.

1769. THEBAIA (*Symb.* $O^3C^{25}H^{14}N$; *Eq.* 205.2) is " prepared in the following manner by Couerbe from the drainings obtained after separating hydrochlorate of morphia by Dr Gregory's process. These are evaporated to the consistence of a syrup; this contains bimeconate of lime, morphia, narceia, meconin, narcotine, and thebaia. Hydrochloric acid is to be added, to separate a black fatty matter containing ulmic acid, which is removed by a skimmer from the surface of the liquid. To the solution thus

purified, ammonia is to be added, which occasions a black deposit of morphia and thebaia. This precipitate is to be dried, powdered, and treated with boiling ether, in which the thebaia, though only slightly soluble, dissolves. When the ether is separated by distillation, the thebaia is deposited in small reddish crystals, which are to be purified by boiling in alcohol with animal charcoal. It is then to be dissolved in ether, and, by spontaneous evaporation, crystals are obtained. Thebaia, thus prepared, is perfectly white, strongly alkaline, and soluble in alcohol and ether. In the first liquid it crystallizes, like the sugar of grapes, in small mammillated crystals, but in the second, in brilliant flat rhombic crystals. When heated to about 266" it fuses, and does not solidify till its temperature is reduced to 130°; whereas narcotine fuses at 338", and solidifies at 266". Codeia fuses at 302°, and meconin at 194°.

" By fusion, thebaia loses four per cent., or two equivalents of water. Concentrated acids convert it into a resinous substance, whereas, when properly diluted, they combine, and form crystallizable salts with it. By friction it becomes negatively electrical. M. Couerbe gives the following table of the colours produced by agitating the peculiar substances contained in opium in a bottle with sulphuric acid and air. Nitric acid oxidizes them so rapidly, that the progress of the oxidation cannot be followed. The experiment is to be made in a four-ounce phial, with six grains of the substance. With nearly half an ounce of sulphuric acid containing nitric acid, strong agitation is to be employed. At first the colour is not very deep, but it is developed in a few minutes.

" Thebaia is rendered instantly red, becoming deeper and deeper in time ; when examined in thin portions, the colour has a yellowish tint.

" Narcotine. At first yellow, and remains so for seven or eight minutes, then becomes red.

" Codeia immediately becomes of a very pale-green colour, which passes to a greenish-red after some time.

" Morphia becomes almost immediately of a green colour.

" Meconin. No immediate effect, but in 24 hours the mixture becomes of a superb-rose colour.

" Narceia immediately becomes nearly of a mahogany colour."

When sulphuric acid, which contains no nitric acid, is employed, then,

" Thebaia gives a rose colour, with a shade of yellow.

" Narcotine, a blood-red colour.

" Codeia, a green colour.

" Morphia, a brown colour.

" Meconin, first a turmeric yellow, and then red.

" Narceia, a chocolate colour."

M. Couerbe obtained from 40 pounds (French) of opium, the following products :—

50 Ounces of morphia,
1 Ounce of meconin,
1½ Ounce of codeia,
¾ Ounce of narceia,
1 Ounce of thebaia.

The narcotine, which remained in the mass, was not extracted."—*Philosophical Magazine and Annals.*

1770. MECONIN (*Symb.* $O^4C^{10}H^5$). This substance, though placed in the present section as one of the ingredients of opium, is not considered to possess alkaline properties, and it differs also from most of the vegetable alkalis in containing no nitrogen. It has been prepared in small quantity by separating it by ether from narceia, as is stated under narceia, and has also been procured in large quantity by other processes.

1771. When opium has been given as a poison, it may in general be detected by its peculiar odour, and by the deep red colour which a solution of a persalt of iron gives, on treating the precipitate, thrown down by acetate of lead from the liquid procured by filtering the contents of the stomach, in the manner described in 1759 and 1760.

1772. From the number of different principles which the infusion and tincture of opium contain in solution, they are decomposed by a great number of substances, many of which must occasionally be present in the liquid contents of the stomach; metallic salts in particular, and astringent matter, produce this effect, so that it is necessary to examine also the solid matter that is obtained when laudanum has been administered as a poison, even though it should have been satisfactorily ascer-

tained that no solid opium has been given along with it. Dr Christison recommends the contents of the stomach to be acidulated with acetic acid, boiled to the consistence of a syrup, and the residue to be boiled with strong alcohol, breaking down any coagulum that may appear on its addition. The solution is then to be evaporated as before, the product dissolved in distilled water, and the solution filtered. By the appropriate tests, the meconic acid and morphia may then be detected in the solution.

I have met with an instance of poisoning by this substance, in which no trace of opium could be detected by chemical reagents a short time after death ; Dr Christison has also mentioned several of a similar description.

1773. With respect to the antidotes to be employed when an over-dose of opium has been given, there is no chemical remedy on which we can depend : the carbonate of potassa has been proposed, to precipitate the morphia from its solution, and prevent it from acting so energetically as it otherwise would do. Recourse should always be had to the stomach-pump when it can be procured, and powerful emetics should be administered till vomiting is excited, giving at the same time large quantities of warm water, and preventing the individual from falling into a state of sleep or stupor, if possible, by forcing him to walk up and down till its effects have passed off. Diffusible stimuli should be given at the same time, taking care to avoid every thing which may render the morphia more soluble, as vinegar or acids, which would only increase its deleterious effects ; though, when the poison has been completely removed, some of them assist materially in restoring the tone of the whole system.

Sect. II.—Quina.

Symb. $O^2C^{20}H^{12}N$. *Eq.* $164.6 = O.16 + C.122.4 + H.12 + N.14.2$.

1774. The beginner cannot be too particular in procuring the specimens of the different varieties of bark which he may require from a source on which he can depend, as there is nothing that is more frequently adulterated than cinchona bark. It is not only often mixed with barks of an inferior quality, or

of a totally different kind, but offered for sale after its active principles have been in a great measure extracted. This is not an imaginary case. It has been noticed in other works ; and I have myself met with specimens of bark in this condition. It is usually reduced to powder, mixed up with a fresh quantity of bark, and sold as a cheap bark to country apothecaries,—a practice which cannot be too much reprobated, and which the medical practitioner ought to be able to detect.

1775. Pour an infusion of galls into a decoction of bark ; a copious white precipitate will appear, the gallic acid which it contains uniting with the alkali and forming an insoluble gallate of quina or cinchonia. If, however, the alkali has been extracted from the bark before the decoction with which the experiment is made be prepared, little or no precipitate will be thrown down. An infusion of galls, therefore, may be used with advantage for distinguishing between good and bad varieties of bark.

1776. Quina is found in the *Cinchona cordifolia* or Yellow Bark, in the *Cinchona lancifolia* or Pale Bark, in the *Cinchona oblongifolia* or Red Bark, and in several other species of bark, all of which contain cinchonia likewise, another vegetable alkali. The yellow bark is usually employed for the preparation of quina, as it contains a considerable quantity of this principle, but very little cinchonia. In the pale bark, again, cinchonia is the alkali that predominates ; while in the red bark a larger quantity of cinchonia and quina is said to exist than in either of the other varieties of bark. Serturner has pointed out some new vegetable alkalis which exist in the red and yellow barks along with cinchonia and quina, and which are considered more powerful in their febrifuge action than either of the former ; they are not easily procured in a pure form. Thirty-four pounds of good yellow bark afford about one pound of Disulphate of Quina.

Quina and cinchonia are the principles on which the peculiar properties of Peruvian bark depend. The existence of a peculiar principle in which its characteristic qualities reside was pointed out by Dr Duncan, who gave it the name of cinchonine ; a discovery of great interest, and which first directed the attention of chemists to those researches in organic chemistry, equally

interesting as a branch of chemical science, and important in
their practical applications.

1777. Quina may be easily procured by decomposing a solution
of the disulphate of quina in water by slaked lime ; this earth
immediately combines with the sulphuric acid, sulphate of lime
and quina being precipitated together. The precipitate is then
to be digested in alcohol, which dissolves the quina, and leaves
the sulphate of lime.

1778. Evaporate the alcoholic solution of quina till it is con-
centrated ; quina is deposited, but not in crystals. It may be
procured in crystals, however, by the spontaneous evaporation of
its alcoholic solution.

1779. Put a blue test-paper into a solution of quina in alcohol ;
it will be immediately rendered green, in the same manner as by
solutions of the common alkalis.

1780. If a solution of quina or of any of its salts be mixed
with a strong solution of chlorine, and ammonia be added, a
beautiful green colour will be observed, which will become red
on the addition of an acid. This is a delicate test, and will de-
tect a grain of the alkali in a pint of solution. The chlorine
and ammonia water must be concentrated, as in the detection of
morphia. (Dr Meeson.)

1781. Add quina to a small quantity of sulphuric acid diluted
with five or six times its bulk of water ; the quina will neutralize
the sulphuric acid, and a solution of the disulphate of quina will
be obtained, which will yield crystals on evaporation.

1782. Throw a little quina on a red-hot iron plate, or on some
red-hot cinders. It will inflame and be completely decomposed,
the usual products of the combustion of vegetable matter being
formed, and nitrogen gas being disengaged.

1783. Heat a little in a close vessel, or in a glass-tube, that it
may not be exposed freely to the action of the air ; in addition
to the products that are generally obtained during the decompo-
sition of vegetable matter by heat in close vessels, a small quan-
tity of carbonate of ammonia will be disengaged, indicating the
presence of nitrogen.

1784. The DISULPHATE OF QUINA is the most important
compound of this alkali, and is preferred for medical purposes to
the quina itself, as it possesses all the virtues of the latter, while
its solubility enables it to act more powerfully and uniformly,

quina being very sparingly soluble in water, though it is readily dissolved by alcohol and ether. It has an intensely bitter taste, similar to that of pure quina. It consists, when first crystallized, of 8 eqs. of water, 2 of quina, and 1 of sulphuric acid ; but when exposed to the air and effloresced, it loses 6 eqs. of water.

1785. The preparation of disulphate of quina, though usually considered a difficult process by the beginner, may be easily conducted on the small scale in the following manner. Reduce 3000 grains of yellow bark (1776) to a coarse powder, bruising it In a mortar, and boil it for twenty minutes in a large earthen evaporating basin, with eight or ten times its weight of water acidulated with half an ounce by measure of sulphuric acid. Strain the decoction through a large woollen or linen cloth, return the bark, and boil it again with the same quantity of water and acid, straining it as before, and washing it afterwards with a little water. The decoctions are then to be mixed, and slaked lime in fine powder is to be added to them till the liquid becomes alkaline, examining it constantly with this view till it tinges the common test-paper green, and assumes a dark colour, a precipitate beginning to appear, and leaving a clearer liquid above. This is the first stage of the process, and when the bark is good, about 800 grains of lime are in general required to produce the effect described. The bark contains the quina in combination with Kinic acid, a vegetable acid with which it is generally associated ; and by boiling it with sulphuric acid and water, the kinate of quina is decomposed, the sulphuric acid combining with the quina, and forming sulphate of quina, which remains in solution along with the other matters that the bark contains which are soluble in water. The woody fibre is scarcely affected by the acid. In this manner, then, the quina is separated from the bark, and the solution which is obtained contains essentially sulphate of quina with a considerable excess of sulphuric acid, which promotes its solubility in the water. When the lime is added, it combines with the excess of sulphuric acid, and also with the sulphuric acid of the sulphate of quina, forming sulphate of lime, and the quina, now losing the sulphuric acid that retained it in solution, is precipitated, mixing as it falls with the sulphate of lime. The liquid should be constantly agitated during the addition of the

lime. By filtration, the quina and the sulphate are separated from the liquid, which still retains in solution most of the other matters that were dissolved at first by the water.

1786. The next stage of the process consists in digesting the mixture of quina and sulphate of lime in alcohol, after it has been completely dried by exposure to a gentle heat on a sand-bath, or by placing it on a plate before the fire. It should be reduced to powder for this purpose, and mixed intimately with a small quantity of alcohol in a mortar, after which, four or five times its bulk of this fluid may be added, digesting for two or three hours, and then decanting the clear liquid that is obtained on allowing it to remain at rest for a short time. This should be repeated several times with fresh alcohol, till it ceases to acquire a bitter taste. The alcohol dissolves the quina, and leaves the sulphate of lime, and by evaporating the mixed liquids, the quina is obtained sufficiently pure for the preparation of the disulphate.

1787. The alcoholic solution of quina should be evaporated in a glass-retort, that the alcohol may not be lost, as it may be used repeatedly for the same process; and the evaporation may be continued by the heat of a water-bath, a sand-bath, or chauffer, till a viscid liquid is procured. Should a chauffer or lamp be used, the beginner must take care to allow the distillation to go on slowly, and to avoid carrying it too far, lest part of the quina be decomposed by the heat. When a considerable portion of the alcohol has been distilled over, the liquid boils irregularly, a violent ebullition taking place, which soon ceases altogether until it is again renewed as violently as before; this may be in a great measure prevented by putting in small coils of platinum-wire, or of any solid matter that will not be affected by the liquid. None of these must be put in, however, while the ebullition is actually going on, otherwise a large quantity of vapour will rise immediately in the retort, and carry a portion of the liquid over into the receiver; after allowing it to cool for a few minutes, they may be safely introduced. In general, the evaporation may be carried on till a quantity of solid matter begins to be deposited on the sides of the retort, which will appear some time after small globules of an oily-looking matter are seen on the surface of the liquid, rolling about in a very singular manner. On the large scale, the alcohol is usually dis-

tilled by a water-bath, or by a pipe conveying steam made to
pass through the interior of the still ; but when only a small
quantity of materials is employed for illustrating the nature of
the process, this may be done more conveniently with a glass-
retort heated by a chauffer.

1788. If the distillation be stopped when the appearances
that have been described are seen, the fluid that remains in the
retort will divide into two parts as it cools.   The upper part is
a bitter milky liquid, which has an alkaline reaction, turning
the vegetable blues to a green ; and the lower part is composed
of a viscid substance, which also contains a considerable quan-
tity of quina.   Hot water may then be poured upon the residue
in the retort, and sulphuric acid diluted with four or five times
its bulk of water is to be added cautiously to the liquid till it is
completely neutralized, using a small pipette for this purpose, ex-
amining it constantly with a test-paper, and adding a very slight
excess of acid.   The solution of disulphate of quina thus pro-
cured must be boiled with a little animal charcoal, and con-
centrated by evaporation, after which stellated crystals of the
disulphate will be deposited as it cools.   By mixing a little ani-
mal charcoal with the solution, the crystals may be obtained
quite pure by the first crystallization.

1789. If the solution should not deposit crystals, but remain
thick like gum-water, by diluting it with a little water, and
again heating it for a short time, the disulphate will be deposited
in crystals.   They have a fine pearly lustre, are completely de-
composed by heat, alkalis, and alkaline earths, the latter preci-
pitating quina from the solution of the disulphate in water.

1790. Disulphate of quina may be prepared without alcohol, by
a process pointed out by MM. Henry and Plesson, the details
of which may be seen in the Quarterly Journal of Science for
July 1827.   It has also been prepared by Pelletier by an analo-
gous process, in which oil of turpentine has been substituted for
alcohol ; but the product is a little less than when alcohol is
used.

1791. According to the process of the London College, after
boiling the bark in very dilute sulphuric acid, the sulphuric
acid is precipitated by adding hydrated oxide of lead till it is
nearly neutralized.   To the filtered liquid ammonia is then
added to precipitate the quina, which is washed with water till

the quina is free from this alkali. The quina is then neutra-
lized by diluted sulphuric acid, and boiled with animal charcoal.
It may then be filtered and crystallized.

1792. Heat some disulphate of quina in a glass-bottle, by
putting it cautiously into hot water. It will assume a phos-
phorescent appearance, a pale light being evolved.

1793. Disulphate of quina bearing a very high price, it is
frequently adulterated with a variety of substances. Earthy
matter may be detected by exposing it to a red-heat, when all
the disulphate of quina will be decomposed or volatilized, no-
thing remaining but the earthy matter with which it may have
been mixed.

1794. It has lately been adulterated to a considerable extent
with stearine, one of the component parts of most fatty matters,
which bears a considerable resemblance in its external appear-
ance to this salt. They are easily separated, however, by di-
gesting the mixture in water acidulated with sulphuric acid, a
supersulphate of quina being formed, which is very soluble,
and is dissolved by the water, while the stearine is left, and
may be melted into a greasy fluid by a gentle heat.

1795. Disulphate of quina is also occasionally adulterated
with sugar, which may be detected in the following manner.
Dissolve the suspected disulphate in water, and add a solution
of the carbonate of potassa, which will immediately precipitate
carbonate of quina; filter the liquid, evaporate it cautiously
with a very moderate heat, and digest the residue in alcohol.
If any sugar should have been mixed with the disulphate, it will
be dissolved by this fluid, and its amount may be ascertained
by evaporating the liquid.

1796. SULPHATE of QUINA may be procured by adding sul-
phuric acid to the disulphate in solution. It is much more so-
luble than the disulphate.

1797. ACETATE of QUINA may be prepared in the same man-
ner as the disulphate.

1798. TARTRATE, and GALLATE of QUINA, may be obtained
by mixing solutions of the gallate, and tartrate of potassa, with
a solution of disulphate of quina. They are insoluble in cold
water, but soluble in hot water and in alcohol.

CINCHONIA. *Symb.* $OC^{20}H^{12}N$. *Eq.* 156.6.

1799. This vegetable alkali may be prepared in the same manner from the pale bark as quina is procured from the yellow bark, and bears a great resemblance to it in all its leading properties. It differs from it principally in being easily crystallized, and in the quantity of acid which it can neutralize.

SECT. III.—STRYCHNIA.

Symb. $O^3C^{30}H^{16}N$. *Eq.* $237.8 = O.24 + C.183.6 + H.16 + N.14.2$.

1800. This vegetable alkali is usually prepared from nux vomica, in which it exists in combination with a peculiar vegetable acid which has received the name of *Igasuric acid*, mixed also with a little *Brucia* (another vegetable alkali), gum, colouring matter, a fatty matter, and woody fibre. The following is the method of procuring it :—The nux vomica is to be bruised in a mortar, and macerated in successive portions of water, and the liquid is to be evaporated to the consistence of an extract after it has been filtered ; the igasurate of strychnia will be dissolved, and the solution will also contain a portion of gum, colouring matter, fatty matter, and brucia. By digesting the extract in alcohol, the gum will be separated, while the other substances will be dissolved ; and by evaporating the alcoholic solution to the consistence of an extract, and macerating it in cold water, the fatty matter will be left undissolved. The solution is then to be heated, and an excess of lime-water is to be added to it. The strychnia and brucia will be precipitated along with the colouring matter ; and on macerating the precipitate in weak alcohol, the brucia and colouring matter are dissolved, while the strychnia is left. If the strychnia be then dissolved in hot alcohol, minute crystalline grains of strychnia will be deposited as it cools.

1801. According to the process of the London College, a solution of the igasurate of strychnia is prepared by boiling the

nux vomica in alcohol, evaporating, and making a watery solution. On adding magnesia, igasurate of magnesia is formed, with which the strychnia is mixed. By digestion in alcohol, the strychnia is dissolved and separated from the igasurate of magnesia. The alcohol being separated by distillation, the strychnia is converted into a sulphate by adding diluted sulphuric acid, and crystallized. The crystals when dried and pressed are to be dissolved in water, and the strychnia precipitated by ammonia. Lastly, the precipitated strychnia is boiled in alcohol, which deposits crystals as it cools.

1802. Strychnia possesses the usual properties of a vegetable alkali, and has an intensely bitter taste. It is one of the most powerful poisons belonging to the vegetable kingdom. It is very sparingly soluble in water, and is usually said to be insoluble in this liquid ; it communicates to it, however, a distinct bitter taste, even when mixed with a very large quantity of this liquid. 1000 parts of nux vomica contain only five or six of strychnia. Exposed to a strong heat it is decomposed. Heated with sulphuric acid, hydrosulphuric acid is evolved. Its salts are soluble in water, intensely bitter, and act as powerful poisons.

1803. Warm tea and infusion of galls have been recommended as antidotes.

VERATRIA.

Symb. $O^6C^{34}H^{22}N$.   *Eq.* 292.28.

1804. Veratria was prepared originally from the *Veratrum album* or white hellebore, but is now procured in general from the cevadilla, the seed of the *Helonias officinalis*. The following is the process adopted by the London College.

1805. Bruise two pounds of cevadilla, and boil them for an hour in a gallon of alcohol, condensing the vapours of the alcohol, which would otherwise be lost. Decant the solution, and repeat the boiling a second and a third time, using on each occasion another gallon of alcohol as at first. The cevadilla being pressed and drained, the mixed decoctions are then to be evaporated to the consistence of an extract, which contains essentially *gallate of veratria.*

The extract is boiled three or four times in successive portions of water, previously acidulated with diluted sulphuric acid. The liquid thus procured contains the sulphate of veratria, and must be evaporated to the consistence of a syrup by a very gentle heat.

Magnesia may now be added in excess to the impure sulphate of veratria, when sulphate of magnesia is formed, and the veratria is set at liberty.

From the preceding mixture, veratria is obtained by boiling in spirit of wine, separating the alcohol afterwards by distillation.

The veratria is still impure, and is again converted into a sulphate by the addition of dilute sulphuric acid, boiling the solution with animal charcoal.

Lastly, ammonia is added to the solution of the sulphate, when sulphate of ammonia is formed in solution, and the veratria is precipitated.

1806. Veratria is usually procured in the form of a colourless powder. It has a hot and acrid taste, and excites violent and often dangerous sneezing. It melts on exposure to a moderate heat, producing a yellowish matter like resin. At a higher temperature it is entirely decomposed and dissipated. Alcohol is its proper solvent, and ether takes up a little; but water only a very minute quantity, so that it is usually said to be insoluble in this liquid.

1807. From recent analyses, it appears that there are other vegetable alkalis associated with the veratria in the various vegetable substances from which it is procured.

lition for six or eight hours. The reaction between the oil and
the air proceeds more quickly than in the preceding case, and
the oxide of lead is reduced. The thick compound procured is
usually termed VARNISH, and is much employed as a basis in
making paints.

1813. Mix 48 parts of olive oil with 1 of nitrate of mercury.
The mixture becomes hard in twenty-four hours, if the olive
oil be free from other fixed oils. If any of the latter be pre-
sent, the olive oil may thicken, but does not harden. The
nitrate used for this purpose is prepared with 6 parts of mer-
cury, and 7½ of nitric acid of sp. gr. 1.35, and contains much
hyponitrous acid. Hyponitrous acid alone produces a similar
effect.

1814. Expose RAPESEED, OLIVE, MUSTARD, or ALMOND OIL to
the air, in the same manner as linseed oil, par. 1811. They
ultimately become solid, and resemble tallow more than varnish.
Hence they have been named *Fat Oils.*

1815. COCOA NUT OIL, PALM OIL, and NUTMEG OIL are termed
solid oils ; they are the more important of those that are pro-
cured in the solid form.

1816. Mix some sulphuric acid with half its bulk of a fixed
oil ; the mixture immediately becomes black and clotted, and a
considerable quantity of sulphurous acid is soon disengaged.

1817. Repeat this experiment with oil of turpentine instead
of a fixed oil. A similar reaction ensues, but the mixture does
not become thick.

1818. Mix some nitric acid with another portion of the same
fixed oil in a deep glass, taking care to avoid the sparks that
are thrown out. A more violent reaction takes place than in the
preceding case, and a large quantity of gaseous matter is dis-
engaged.

1819. Mix some castor-oil and alcohol in a glass or bottle,
shaking them together ; they unite in any proportions, and form
a transparent and colourless liquid. Other fixed oils are in ge-
neral insoluble in alcohol. Throw some of the above compound
into water ; the alcohol combines with the water, and the oil is
set at liberty. The affinity between alcohol and castor oil is
not great, as they often separate spontaneously when kept for
a long time.

1820. Expose a quantity of some fixed oil to heat in a re-

tort, over a good chauffer, collecting the liquid products in a receiver. A large quantity of inflammable gaseous matter is disengaged, and a thin empyreumatic oily liquid condenses in the receiver, very different from the fixed oil subjected to distillation.

1821. Mix one part by weight of the water of ammonia and eight parts of olive oil. A soap or liniment is immediately formed, called *Oleum Ammoniatum* by the Edinburgh College.

1822. By boiling fixed oils, fats, or resins with a solution of potassa or soda, soaps of different kinds may be obtained, the potassa giving a soft, and the soda a hard soap. From the experiments of Chevreul, it appears that the alkali does not combine directly with the oil, but that the latter is decomposed, the stearine and elaine being converted into what are now termed *Margaric* and *Oleic* acids, which form soap by uniting with the alkali.

1823. There is a great variety of these acids, according to the nature of the oily or fatty matter from which they may have been prepared.

1824. When the fixed oils are changed into these peculiar oily or fatty acids by heating them with fixed alkalis and water, a new product, viz. GLYCERINE, is also detached from the oily or fatty substances. The acids combine with the alkalis and constitute soap; the glycerine remains in solution. It is there associated with a little free alkali, which must be neutralized by sulphuric acid. On evaporating to dryness, alcohol may be used to extract the glycerine; the solution affords a syrupy fluid when concentrated. Glycerine is soluble in water and alcohol, has a sweet taste, does not crystallize, nor does it enter into the vinous fermentation.

1825. MARGARON, STEARON, and OLEON are the names given by Bussy to the products obtained by distilling a mixture of margaric, stearic, or oleic acids with 1-4th of their weight of lime, and purifying the fatty or oily compound obtained, by repeated solution in alcohol. Margaron and stearon can be crystallized, but oleon is liquid at natural temperatures.

1826. Digest some soap in alcohol; a solution is obtained which is frequently used as a test for the presence of earthy salts in water.

1827. By distilling the greater portion of the alcohol from

an alcoholic solution of soap, and allowing the residue to con-
solidate, transparent soap may be obtained ; the strong solution
may be poured into a mould while still warm.

1828. Pour a little of the solution of soap in alcohol into a
glass of distilled water. The solution of the soap will diffuse
itself through the water, which will remain quite transparent
and colourless.

1829. Soap is decomposed by numerous acids, which combine
with the alkali, separating the oleaginous acid. Alkaline earths
form a white precipitate with the oleaginous acid, leaving the
alkali in solution.

1830. Add some of the solution of soap in alcohol to a glass
of water, in which a little of the sulphate or hydrochlorate of
lime has been dissolved. The acid in combination with the lime
unites with the alkali of the soap, forming a salt which remains
in solution ; and the margaric and oleic acids unite with the lime,
an imperfect soap being produced, insoluble in water, which is
deposited in the form of a white curdy precipitate.

1831. Similar experiments may be made with a solution of
soap and other soluble earthy salts, and also with solutions of
most of the metallic salts.

1832. Fixed oils combine also with oxide of lead, forming
thick tenacious compounds or plasters. In preparing them, the
oxide of lead should be reduced to a very fine powder, and ex-
posed to heat with the oil and water till they have combined
into a mass of a uniform consistence.

The combination may be effected by heating the mixture
without water, but then a portion of the oil is almost always
decomposed from the high temperature which the materials are
apt to acquire when no water is used, and the compound has a
black colour from a portion of carbon which is disengaged.
The oxide of lead is also apt to be reduced by the action of the
warm oil. They may be obtained of various degrees of con-
sistency by mixing them with different proportions of wax and
resin.

1833. Put ten or twelve grains of phosphorus into a Florence
flask with three or four ounces of olive oil, and digest the mix-
ture for some time with a very gentle heat. Part of the phos-
phorus is dissolved, and the oil appears luminous in the dark,

whenever it is exposed to the air, the phosphorus combining with the oxygen of the air.

1834. Turpentine is the name given to the viscid substance which exudes from incisions made in the pinus abies and the pinus silvestris. It is composed of a volatile oil and two resinous compounds.

1835. Mix turpentine with water, and subject it to heat in a still. A retort may be used on the small scale. The volatile *oil of turpentine* passes over into the receiver along with the water, and the *resin* is left.

1836. Add to oil of turpentine a little vegetable blue. It is in general immediately reddened, from the presence of a little vegetable acid.

1837. Some varieties of oil of turpentine boil at 312°, and others at 350°, from which it has been inferred, that there are different species of oil of turpentine.

1838. Oil of turpentine, exposed for a long time to the action of oxygen gas, absorbed 118 times its bulk the first year, but a much smaller quantity afterwards, the absorption probably being arrested by the carbonic acid, hydrogen, and nitrogen, which had been liberated at the same time. The origin of the nitrogen has not been so distinctly traced as that of the other gases.

1839. Small quantities of chlorine are absorbed by oil of turpentine. Iodine is very soluble in it.

1840. Dip a piece of paper in oil of turpentine, warm it slightly if very cold, and introduce it into a large vase containing chlorine ; the oil of turpentine is usually inflamed, and much carbon separated, the chlorine combining with its hydrogen.

1841. Camphene is a term now applied by many to oil of turpentine which boils at the temperature of 313°, and is regarded as a compound of ten eqs. of carbon and eight of hydrogen. *Symb.* $C^{10}H^8$.

1842. Citrene is the name given to the volatile oil of lemons. It resembles camphene in its chemical properties, though differing much from it in its odour. It is usually procured by expression. With hydrochloric acid it forms the hydrochlorate of citrene, which resembles artificial camphor.

1843. Orange Flower Oil is procured by distillation with water from the flowers of the orange tree. It is sparingly soluble

in water, producing with this fluid the fragrant orange-flower water.

1844. OIL OF CLOVES is very hot to the taste, and is composed of two distinct oils; one of these resembles camphene, but the other is not so volatile.

1845. HYDRURET OF BENZULE, or VOLATILE OIL OF BITTER ALMONDS.   This substance has attracted much attention of late from the number of changes of which it is susceptible, and the circumstances under which it is produced.   The fixed oil of bitter almonds, when prepared by expression, and without heating the materials, contains no volatile oil; but when the residuum after the expression of the fixed oil, or the bruised bitter almond before any oil has been expressed, is subjected to the action of heat with water, a volatile oil may be obtained by distillation, which is now considered not to have pre-existed in the almond, but rather to have been produced by the action of heat upon the materials used.   It contains a considerable quantity of hydrocyanic acid, and is extremely poisonous.   Vogel also maintains, that, even after the hydrocyanic acid has been entirely separated, the oily matter that remains is a powerful poison.

1846. The elaborate investigations of Wöhler and Liebig in reference to the constitution of this oil have shewn, that it may be regarded as a hydruret of a peculiar base, which has been termed BENZULE. This has not been procured in a free state, but may be separated from one substance and transferred to another in numerous combinations. The following table gives a view of the composition of Benzule and the more important combinations into which it enters :—

Benzule,	. . . . . .	Bz or $O^2C^{14}H^5$.
Oxide, or Benzoic Acid,	. . .	$O + O^2C^{14}H^5$.
Hydruret, or distilled oil of bitter almonds,		$H + O^2C^{14}H^5$.
Sulphuret,	. . . . . .	$S + O^2C^{14}H^5$.
Cyanide,	. . . . .	$C^2N + O^2C^{14}H^5$.
Chloride,	. . . . . .	$Cl + O^2C^{14}H^5$.
Bromide,	. . . . . .	$Br + O^2C^{14}H^5$.

1847. AMYGDALIN is the term applied to a white crystalline compound which is procured from the bitter almond.   To prepare it, take the residuum left after expressing the fixed oil of the bitter almond.   Boil it in highly rectified alcohol.   Separate

from the solution when cold a little fixed oil, which is soon deposited, and filter. Amygdalin is slowly deposited from the alcoholic solution ; and, by concentrating the remaining solution and adding ether, an additional quantity is precipitated. The amygdalin is compressed and dried, and boiled again in alcohol, from which it is deposited in crystals as it cools.

1848. Amygdalin is inodorous, but has a sweetish bitter taste. It is soluble in alcohol, but insoluble in ether. Its action with water has been imperfectly investigated. It is soluble in a solution of potassa; and, when this is boiled, ammoniacal gas is evolved, proving the presence of nitrogen in amygdalin.

1849. EMULSIN is the term applied to a substance found in the almond, which resembles vegetable albumen ; and, from a mutual reaction between it and amygdalin, the volatile oil and hydrocyanic acid procured by distillation are supposed to arise.

1850. OIL OF ROSES is a soft solid below the temperature of 80°, and is procured by distillation from the petals of the Rosa centifolia, after mingling them with water. The quantity of oil in the roses of this country is too small to admit of the process being carried on economically, except with the view of communicating a small quantity to water.

1851. Pour a little oil of turpentine and fixed oil on two pieces of paper, and expose them to heat before the fire. The oil of turpentine is soon volatilized, and no stain is left upon the paper ; but the fixed oil does not disappear unless the paper be exposed to a temperature sufficient to destroy it.

1852. Mix a small quantity of any of the volatile oils with three or four times its bulk of water, and expose the mixture to heat in a glass-retort placed over a chauffer, condensing the product in a receiver kept cold by water. The volatile oil rises in vapour at the same temperature as the water, and is collected in the receiver ; when distilled alone, volatile oils in general require a temperature upwards of 300° before they boil.

1853. The sulphuric and nitric acids act violently upon the oils when mixed with them ; and all experiments made with these substances must be cautiously performed. Considerable heat generally accompanies the action, a large quantity of gaseous matter is suddenly extricated, and the mixture often inflames. Mix one dram of sulphuric acid by measure with four drams of strong nitric acid in a glass, tied to one extremity of a stick or

iron rod at least three feet long, and pour the mixture upon two
drains of oil of turpentine placed in a small cup or evaporating
basin under the chimney; the turpentine is immediately in-
flamed, and a large quantity of gaseous products disengaged.   If
the experiment be performed in the open air, innumerable little
vesicles of a dark colour very frequently appear, which float for
a short time in the surrounding atmosphere ; they are probably
composed of carbon.

1854. Put a small crystal or about a grain of the powder of
chlorate of potassa on paper, pour a little oil of turpentine over
it, and touch it with a glass-rod dipped in sulphuric acid.   Bisul-
phate of potassa is formed, and peroxide of chlorine (chlorous
acid) is disengaged, which immediately causes the oil of turpen-
tine to take fire.

1855. CAMPHOR, or OXIDE OF CAMPHENE, is a very inflammable
solid, which melts at 288°, and boils at 400°, having a fragrant
agreeable odour.   Besides the ordinary camphor, procured by
distillation from the Laurus camphora, many other varieties have
been described.

1856. Dissolve camphor in alcohol, and pour the solution into
water.   The alcohol combines with the water, and the camphor
is precipitated.

1857. When camphor is to be reduced to powder, a few drops
of alcohol added to it enable it to be easily pulverized.

1858. Dissolve camphor in strong nitric acid, till a solution
appears as an oily fluid floating upon the top of the remaining
acid.   Decant the solution and pour it into 20 times its bulk
of water ; the acid is withdrawn, and the camphor deposited.
By heating it with nitric acid, camphoric acid is formed.   Strong
acetic acid dissolves camphor, the solution being decomposed,
as in the preceding cases, by the action of water.

1859. ARTIFICIAL CAMPHOR.   Cool oil of turpentine by ice,
and pass dry hydrochloric acid through it till it ceases to ab-
sorb any more.   When the liquid thus procured is allowed to
remain at rest for a day or two, the artificial camphor is depo-
sited in crystals, which are purified by compression in bibulous
paper, dissolving them subsequently in alcohol, from which the
camphor may be separated by crystallization.   It varies in its
qualities according to the oil of turpentine from which it is pre-
pared.   It is regarded as a compound of one equivalent of hy-

drochloric acid and one of camphene, and may accordingly be termed the hydrochlorate of camphene. It is highly inflammable, and its odour resembles considerably that of camphor.

1860. BALSAMS are viscid fluids or solids procured from various vegetables by exudation. They contain *Benzoic acid*.

1861. AMBER is regarded as a concreted balsam. In a chemical point of view it is principally interesting as affording on sublimation succinic acid, which is employed in precipitating per-salts of iron after combining it with ammonia.

1862. RESIN, COMMON RESIN, or COLOPHONY is the brittle solid that is left after the volatile oil of turpentine has been expelled from turpentine by heat. Under the general term of resins, however, a great variety of substances are included. Their properties have lately attracted much attention, many new compounds having been procured from them. They are in general fusible, highly inflammable, and insoluble in water, but soluble in alcohol, oil of turpentine, and other oily substances.

1863. Expose some common resin to heat in an iron cup. It soon melts, and by increasing the heat it is completely decomposed, a large quantity of gaseous matter being disengaged, which burns with a rich flame, producing a large quantity of smoke, and leaving a small quantity of a black matter, composed principally of carbon.

1864. Dissolve some resin in alcohol, and throw the alcoholic solution into water ; a copious precipitate is thrown down immediately, the water combining with the alcohol which had dissolved the resin, and separating the latter in the powdery form.

1865. CAOUTCHOUC is the concreted juice of the *Ficus elastica*, usually darkened in its colour by the action of smoke upon it. It is fusible at 248° ; and. is decomposed, and burns with much smoke, when exposed to the action of the air at a higher temperature. By destructive distillation, Mr Enderby and Mr Beale have procured various oily products, which have been examined more particularly by Bouchardat. These are—

Eupion and quadro-carbureted hydrogen, similar to what may be procured by other processes.

CAOUTCHEENE, a new volatile oil, very inflammable, and boiling at a temperature between 50° and 60° ; it is extremely light, its sp. gr. being 0.65. HEVEENE, another oily substance, much

less volatile than the preceding, requiring a temperature of about 600° for ebullition, and having a specific gravity of 0.90.

1866. Caoutchouc softens in water, so that one portion can then be fixed or agglutinated by pressure with another. Ether freed from alcohol by washing with water, dissolves this substance; the ether in this condition containing a portion of water. Oil of turpentine and naphtha are the solvents more generally employed. According to Mr A. Andrews, if it be cut into fine threads and immersed in common sulphuric ether, or a solution of an alkali (carbonate of soda 2 oz. to a pint of water may be used), and then put into oil of turpentine, it dissolves with facility; and when spread on cloth and exposed to a dry atmosphere, it speedily dries and assumes its original properties, usually in twenty-four hours.

1867. Calico, linen, or articles of clothing, may receive a coating with this solution, sufficient to render them waterproof, without materially altering their general appearance or injuring their pliability. See par. 1881.

1868. BEE's WAX resembles the preceding substances, and may be classed along with them, though of animal origin. It is purified by melting it in water, spreading it out into thin ribands, and exposing it afterwards to the action of light, air, and moisture. Pure wax melts at 150°, and burns with a brilliant light at a higher temperature, as in the common wax candle. It is insoluble in water, resists the action of hydrochloric, hydrofluoric, and other powerful acids, but is soluble in boiling alcohol, and oil of turpentine, It is composed of two distinct principles, CERIN and MYRICIN, resembling each other considerably; but they fuse at different temperatures, are unequally soluble in alcohol, and differ also in other less important properties. Many varieties of wax have been pointed out which have been procured directly from the vegetable kingdom.

COMPOUNDS PROCURED BY THE DESTRUCTIVE DISTILLATION OF WOOD AND OTHER SUBSTANCES.

1869. AQUEOUS HYDRURET OF CARBON, or PYROXILIC SPIRIT, is the name given to a compound of oxygen, carbon, and hydrogen, in which these elements are associated in proportions which might form one eq. of water and one of hydruret of carbon. It has unfortunately received many different appellations, as *Pyroligneous Ether*, *Hydrate of Carbohydrogen*, *Hydrate of Methylene*, *Bihydrate of Methylene*. Its symbol is OCH^2, or $\cdot H + HC.$*
*METHYLENE (from μεθυ wine, and ὑλη principle) is the term applied to a compound of one eq. of carbon and one of hydrogen, which is considered to have one-half of the density of the hydruret of carbon or olefiant gas. It has not been insulated, but it is believed to exist in numerous combinations, and is the supposed base of pyroxilic spirit. A great number of compounds have been lately formed containing this substance, as the sulphate, nitrate, and acetate of methylene; but the pyroxilic spirit is the most important. METHYLE is a term proposed by Dr Thomson to designate a compound (C^2H^3) which he considers might be regarded as the base of pyroxilic spirit.

1870. Pyroxilic Spirit is procured with the aqueous fluid obtained on subjecting wood to destructive distillation. It is separated from the tar, and a tenth part being removed by distilling again, the pyroxilic spirit is procured from this by repeated rectification, distilling it ultimately after mixing it with lime, which retains any acetic acid and water, and causes the evolution of ammonia.

1871. Pyroxilic spirit is a transparent, colourless, and inflammable fluid, resembling alcohol in appearance, burning with a similar flame, and mixing in all proportions with water. It boils at a temperature which has been stated as low as 137° and as

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* In several works, the atom is doubled, being represented by $O^2C^2H^4$.

high as 150°.   Exposed to air and spongy platinum, formic and acetic acids are produced.   If the pyroxilic spirit be dropped in minute successive quantities upon the spongy platinum, incandescence quickly takes place, and then carbonic acid is one of the principal products developed.

1872. Dry chlorine and vapour of pyroxilic spirit produce hydrochloric acid with explosive violence (Kane).   When the liquid spirit is distilled after mixing it with the chloride of lime, a new compound is formed which Dumas has termed Chloroform.

1873. Pyroxilic spirit combines with alkalis and earths, and many salts, forming, it is presumed, definite combinations with them, as alcohol does.   It also dissolves a number of organic principles.   Mixed with four parts of aqueous sulphuric acid, a gas is disengaged isomeric with alcohol, half of the water of the pyroxilic spirit being removed.   It is considered that though this compound may be isomeric with alcohol, its atomic weight may be double or one half of that of alcohol.   It has an ethereal odour, burns like alcohol, and is condensed by water.

1874. PYROACETIC SPIRIT or ACETONE. *Symb.* OC^3H^5. This fluid is prepared in general by destructive distillation from acetate of lime, rectifying the liquid thus obtained by repeated distillations from a retort heated by a water-bath.   Chloride of calcium is mixed with it to retain water.

1875. Pyroacetic spirit is transparent, colourless, and inflammable, burning with a flame which resembles that of ether.   It boils at 132°, and combines in any proportion with water.

1876. METACETONE is the term applied to a colourless liquid prepared by heating sugar with dry lime, acetone being formed at the same time and mixed with it.   It is colourless, insoluble in water, combines with alcohol and ether, and boils at 183°.

1877. BENZINE is the name applied by Mitscherlich to the bicarburet of hydrogen, which is procured by heating benzoic acid with lime.   His nitrobenzide and sulphobenzide are compounds formed by the action of nitric and sulphuric acid on benzine.

1878. BENZONE is a volatile fluid which was procured by Peligot by heating dry benzoate of lime.   Its symbol is $OC^{13}H^5$.   It has been considered analogous in some of its properties to acetone.

1879. NAPHTHA is an oil obtained by distillation from coal-

tar, similar to that which is found native in many parts of the globe, and known by the name of *Mineral Naphtha.* It is composed of carbon and hydrogen united in the same proportions as in the preceding compounds. It is liquid at natural temperatures, and produces a dense vapour when volatilized. It is purified by mixing it with a small quantity of sulphuric acid and redistilling it in a glass-retort.

1880. There are many varieties of this liquid. Some kinds containing no oxygen are used for preserving potassium, a substance that takes oxygen rapidly from all fluids in which this element exists, and from atmospheric air. But other kinds, more especially those obtained by the first distillation from coal-tar, are totally unfit for this purpose, from the quantity of oxygen which they contain. It is fit for this purpose after having been frequently rectified by distillation, being previously mingled with chloride of calcium, or other bodies which absorb moisture.

1881. Naphtha unites readily with sulphuric ether, alcohol, and oils. It is dissolved by some of the gases, and is supposed to impart to coal-gas its offensive smell. Caoutchouc swells in naphtha, and is dissolved afterwards by the action of long continued heat. The viscid solution is spread upon pieces of cloth, and these closely pressed with the varnished sides in contact, and gently heated to expel the naphtha, form the *waterproof cloth,* which thus consists essentially of two layers of cloth with a film of caoutchouc between.

1882. Mineral naphtha is often procured quite colourless, and may be obtained with a less specific gravity than naphtha from coal-tar. Dr Gregory has procured it by frequent rectification with a specific gravity of .744, having previously heated it alternately with sulphuric acid and a solution of potassa. The product he obtained approached much in its properties to the eupion of Reichenbach. It then boiled at 180°. But the naphtha of coal-tar has usually a specific gravity a little above .800, and boils at temperatures varying from 300° to about 360°.

1883. Naphtha, oil of turpentine, and other volatile oily substances, usually produce a large quantity of smoke, so that they are unfit for use in an ordinary lamp. But if a very broad flat wick be used, and a glass chimney be provided, closed up partially below with plates of mica so that the air can enter solely along either side of the wick upon which the naphtha burns,

the temperature to which the oil is subjected is so great, that all the carbon is consumed, and an extremely brilliant light given out. (See naphtha-lamp, miscellaneous apparatus.)

1884. QUADRO-CARBURETED HYDROGEN.—*Symb.* C^4H^4. *Eq.* $28.48 = C.24.48 + 4$ H. When oil-gas is condensed at the portable gas-works, a liquid is obtained at the same time, from which this compound may be distilled by the heat of the hand ; it must be condensed in a receiver reduced to the temperature of zero by a freezing mixture. It boils at a temperature below the freezing point of water, and is very inflammable. Its vapour is twice as dense as the hydruret of carbon.

1885. BICARBURETED HYDROGEN.—*Symb.* C^2II. *Eq.* 13.24 $= C.12.24 + 1$ H. Prepared from the same fluid that yields the preceding compound, condensing from the vapour that is produced when it boils at the temperature of 180°. Very inflammable, burns with much smoke. It occupies, when in the gaseous form, 1–9th of the space its elements do when uncombined. See par. 1877.

1886. NAPHTHALINE is another compound of carbon and hydrogen, obtained when the distillation of naphtha from coal-tar is conducted at a low temperature ; it condenses in rhomboidal plates in the neck of the retort. According to Reichenbach, naphthaline does not exist in coal-tar, but is produced during its decomposition on the application of heat. It is white when pure, melts at 180°, and boils at 410°. It is insoluble in cold water, but is dissolved by naphtha, alcohol, and ether, and in small quantity by hot water. Chlorine forms two compounds with naphthaline, but when first brought in contact with it, hydrochloric acid is produced. Bromine also can produce hydrobromic acid ; both these substances taking hydrogen from the naphthaline.

1887. NAPHTHALESE, NITRONAPHTHALESE and NITRONAPHTHALASE are the names applied to compounds discovered by M. Laurent, formed by the action of nitric acid on naphthaline.

1888. Naphthaline combines with sulphuric acid, and forms a compound which has acid properties ; it is named the *sulphonaphthalic* acid.

1889. PARANAPHTHALINE was prepared by Dumas from one of the oily fluids obtained by distillation from coal-tar. By cooling it to zero, the paranaphthaline is deposited in minute

crystals ; any naphthaline is separated by boiling alcohol. It may then be purified by distillation.

1890. Paranaphthaline melts at 356°, and boils at 572°, condensing in crystalline plates. Water does not dissolve it ; alcohol and ether, when boiling, dissolve a little, which is precipitated again as they cool. Oil of turpentine is the most powerful solvent.

1891. IDRIALINE is the term applied to a crystalline compound of carbon and hydrogen, which, according to Dumas's analysis, is a tercarburet of hydrogen. It was prepared by distillation from a peculiar ore of mercury termed *Branderz*. It is soluble in oil of turpentine. ' '

1892. PARAFFINE or Petroline, discovered by Dr Reichenbach, and by Dr Christison, is obtained with greatest facility by distillation from the tar of beech-wood, and from the petroleum of Rangoon. On distilling beech-wood tar to dryness, three liquids are procured in the receiver, a light oil at the top, a heavy oil below, and a watery acid liquid between them. By distilling the heavy oil, which is to be separated from the other liquids, and collecting in a receiver by itself the more solid portions, the paraffine is obtained in scales, not very impure. The impurities mixed with it are decomposed by sulphuric acid, on heating to 212°. After digesting for some time with this substance, much sulphurous acid is disengaged, and a colourless fluid floats upon the top ; it contains paraffine and an oil, and, after decantation, it congeals, when the oil may be separated by pressure with bibulous paper. The paraffine remains in the solid form, and is still farther purified by boiling in alcohol, and forming crystals from the alcoholic solution.

1893. It is white, solid, tasteless, inodorous, soluble in alcohol, turpentine, and naphtha, crystallizable, and fuses at 111°. It resists the action of acids, alkalis, and other energetic chemical agents. It burns brilliantly, and without smoke. The name paraffine is derived from the words *parum* and *affinis*, indicating its feeble tendency to enter into combination with other substances.

1894 EUPION. This term is derived from ευ, well, and ήιων, fatty. It is liquid at natural temperatures, boils at 339°, and is soluble in alcohol, ether, and oil of turpentine. Reichenbach procured eupion by a variety of processes from different kinds

of tar, being usually separated from paraffine, with which it is generally associated, by decantation, after the paraffine is deposited in the solid form.

1895. Of late, he has prepared it in a purer form, and with greater facility, from rape-seed oil, by destructive distillation. The first and last products of distillation being separated, the intermediate portions are again distilled. By a third distillation, it is sufficiently purified for mixing it with aqueous sulphuric acid, and distilling it again. It is then washed well with a solution of potassa, adding subsequently aqueous sulphuric acid, and distilling repeatedly, at temperatures reduced gradually at each successive operation, till it rises in vapour at 97°. Chloride of calcium is used previous to the last distillation, to remove effectually any adhering moisture.

1896 KREOSOTE (from κρεας, flesh, and σωζω, I save). This is a transparent, colourless, and inflammable liquid, burning with a smoky flame. Sp. gr. 1.037. Boils at 397°. Its odour is very penetrating, resembling that of smoked meat. It is very antiseptic, and on it the antiseptic powers of smoke and pyroligneous acid depend. It coagulates albumen, from which property its antiseptic virtues are probably derived. It is soluble in alcohol, eupion, and bisulphuret of carbon. By nitric and sulphuric acids, it is decomposed. It combines with alkalis and earths. It has been employed in toothache, being applied in minute quantity where the tooth is decayed.

1897. KREOSOTE has been used in solution in water for preserving animal substances from decay; it can combine with water in two definite proportions. In these the kreosote and water are united in the following proportions :—

	Water.	Kreosote.
First compound,	1.25	+ 100
Second compound,	10	+ 100

1898. Kreosote, when heated with binoxide of mercury, withdraws the oxygen and revives the mercury. Some metallic salts also are reduced by it, as the nitrate of silver. Carbonic acid displaces kreosote from its combinations with the alkalis. Kreosote can also dissolve a number of vegetable colouring matters.

1899. Kreosote is prepared by repeated distillation from the oil distilled from wood-tar, the distillation of the latter never being

carried so far as to develope new products by the decomposition of the tar. The heavy oil that sinks in water is preferred, and separated from any lighter oil and acidulous liquid that may accompany it. Carbonate of potassa is added to neutralize acetic acid; the acetate having been removed, the distillation is commenced. Phosphoric acid is then employed to separate ammonia, and potassa is subsequently combined with it, that the eupion associated with it may float upon the surface and be removed; the potassa is separated afterwards by sulphuric acid, and the kreosote again distilled, when the sulphate of potassa has been removed.

1900. CAPNOMOR, from καπνος, smoke, and μοιρα, a part. Procured by heating the heavy oil of tar with potassa. The picamar is decomposed along with the pittacal and kreosote, the capnomor floating on the surface. On adding sulphuric acid, any eupion is separated, the capnomor combining with the acid. Carbonate of potassa is added to neutralize the acid, and the capnomor is then purified by distillation. It is transparent, colourless, and fragrant. Some specimens prepared in the manner described are powerfully alkaline in their action on the vegetable blues.

1901. PITTACAL is the name given to one of the principles of tar, which gives a blue colour to baryta in solution; this term is derived from πιττα, pitch, and καλος, beautiful.

1902. PICAMAR is the bitter principle of tar. Picamar is derived from *pix*, pitch, and *amarus*, bitter. Obtained by distillation, from oil of tar having a great specific gravity.

1903. TAR is the impure resinous matter obtained from the fir-tree by the action of heat. It is black from the charcoal mechanically mingled with it. Subjected to heat without access of air, acetic acid, water, and many inflammable products, are expelled, the resinous matter being left, blackened by the charcoal, and in the form of PITCH. If all oily matter be expelled, the pitch is hard, but if part be left, the pitch is more or less soft.

1904. Coal subjected to heat, besides the gaseous products and water charged with ammonia, gives a tar resembling in many of its properties that which is procured from wood.

ORDER. IV.

ALCOHOL, ETHERS, and other Inflammable Compounds not included in the preceding Order.

Alcohol.

Symb. OC^2H^3, *or* $\cdot H + 2\,HC$. *Eq. by W.* $23.24 = 0.8 + C.12.24$ $+ H.3$; *or, water* $9 + 14.24$ *olefiant gas.* *Sp. gr.* .796. *Equivalent by volume* □. *Sp. gr. of the vapour of alcohol* 1.607 ; *weight of* 100 *cubic inches* 49.8 *grains.*

1905. Alcohol has not hitherto been prepared by the direct combination of its elements, but is always procured by distillation from liquids that have undergone the vinous fermentation.

1906. The term fermentation is generally used to express those changes which dead animal and vegetable matters in contact with water undergo at natural temperatures. When a solution of sugar undergoes fermentation, an intoxicating liquid is produced, as ale or wine, its properties being more or less modified by the mucilaginous matter and other substances which it may contain. This is termed the Vinous Fermentation, as the product, in all cases of this kind, contains a portion of alcohol, such as is obtained from the fermented juice of the grape. When the liquid becomes sour, the Acetous Fermentation is said to take place, as a quantity of acetic acid or vinegar is then formed. All moist vegetable and animal substances are subject to a still farther change from the spontaneous reaction of their elements, which is termed the Putrefactive Fermentation, when a large quantity of offensive gases is disengaged.

1907. To observe the changes that take place during vinous fermentation, put a solution of three or four ounces of sugar in four times its weight of water into a glass retort or flask, add a small quantity of yeast, which may be procured from any brewery, and put the beak of the retort (or the extremity of a bent tube fitted to the flask, if it be preferred) under the mercury in a pneumatic trough, a jar being placed above it to collect the gas that is disengaged. If there be no proper appa-

ratus for fixing the mercurial jar, the experiment may be performed with a water-trough, but in this case a considerable portion of the gas which is disengaged will be absorbed.   The solution should be placed where it is exposed to a temperature between 70° and 80°; it soon becomes turbid, and a quantity of carbonic acid gas is evolved; a frothy scum collects on its surface, and in a few days it again becomes clear.   On examining it in this state, the sugar is found to have been in a great measure decomposed, and also part of the yeast; and the alcohol which it now contains, with the carbonic acid disengaged, are found to be equal in weight to the sugar which has disappeared. It is by the decomposition of the sugar, then, that these new products are formed, the yeast causing the commencement of the intestine changes by which they are produced, though the precise mode in which it effects this has not been explained.

1908. The manner in which the alcohol and carbonic acid are produced by the decomposition of the sugar may be illustrated by a diagram.   Every 15.12 parts of sugar are composed of 8 parts of oxygen, 6.12 of carbon, and 1 of hydrogen; or of one equivalent of each of these elements, according to some analyses. But if we adopt more recent analyses, there are only 10 eqs. of hydrogen and 10 of oxygen to 12 of carbon; and a portion of water must come into play, to make up an equal number of particles of oxygen, carbon, and hydrogen, if alcohol and carbonic acid be the sole products of vinous fermentation.   Then, 45.36 parts of sugar (or of sugar with two eqs. of water) give one equivalent of alcohol and one of carbonic acid.

Fig. 229.

Symb. 3 OCH = :C & OC²H³.
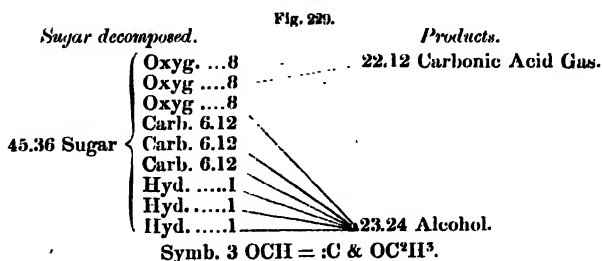
1909. The equivalent number of alcohol is 23.24, consisting of 1 equivalent of oxygen, 2 of carbon, and 3 of hydrogen.   It has been regarded as a compound of 1 measure of watery vapour (1 equivalent) and an equal bulk of olefiant gas (2 equivalents), condensed when in the state of vapour into a volume no

larger than 1 measure, which is therefore its equivalent by volume. The following diagram, similar to one in a former section, shews the manner in which its elements must be arranged according to this opinion.

Fig. 230.

$$23.24 \text{ Alcohol} \begin{cases} \text{Oxyg. ...8} & \text{-------} \rightarrow 9 \text{ Water.} \\ \text{Carb. 6.12} \\ \text{Carb. 6.12} \\ \text{Hyd. .....1} \\ \text{Hyd. .....1} & \text{.....................7.12 Olefiant Gas.} \\ \text{Hyd. .....1} & \text{.....................7.12 Olefiant Gas.} \end{cases}$$
Symb. $OC^4H^3 = \cdot H$ & $2 HC$.
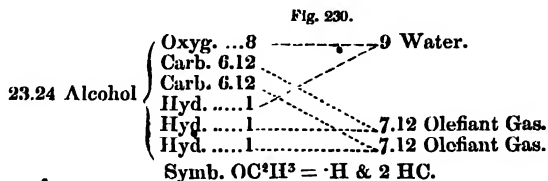
1910. YEAST or FERMENT is the term applied to the substance which separates in small viscid flocculi from all solutions undergoing the vinous fermentation, and which is capable of inducing the same fermentation in liquids similar to those by which it is produced. When dried by a gentle heat it may be preserved without change, but if it be heated in boiling water, it is no longer capable of exciting the vinous fermentation. It consists of carbon, oxygen, hydrogen, and nitrogen.

1911. If the fermented liquor be exposed to heat in a retort, the alcohol, from its greater volatility, rises first, carrying a portion of water along with it, and may be condensed in a receiver. By stopping the distillation when the last portions of alcohol have been disengaged, it may be separated not only from the mucilaginous matters with which it may have been previously combined, but also from the greater part of the water. It is in this manner that brandy is prepared from wine, and whisky from the fermented infusion of malt. The process may be imitated on the small scale by heating half a bottle of wine or ale in a glass-retort (or a still with a refrigeratory may be used, Fig. 53, page 33), continuing the distillation as long as any spirituous liquid comes over. When ale or porter is employed, a capacious retort must be used, as the large quantity of carbonic acid which they contain is disengaged by the heat, and would cause part of the fluid to pass over into the receiver, if the distillation were conducted in a small retort.

1912. On the large scale, soap is often employed in small quantity, to prevent the extreme tendency of the liquid that is distilled to produce froth and boil over.

1913. By repeating the distillation, the alcohol may be separated from an additional quantity of water, which is left in the

retort; but it is impossible in this manner to separate the whole of the water, however often the distillation may be repeated.

1914. Ale and porter usually contain from 4 to 9 per cent. of alcohol, weak wines from 10 to 18 per cent., and strong wines from 18 to 25.   In whisky, gin, rum, and brandy, the amount of alcohol is usually a little above 50 per cent.

1915. To prepare absolute alcohol, as it is termed when completely deprived of water, heat carbonate of potassa to the temperature of 300°, and add it to spirit of wine in a glass-bottle. Shake the mixture well, and then allow it to remain at rest for some time.   If a sufficient quantity of the alkaline carbonate has been added, the liquid divides into two parts ; that which floats above is the alcohol, deprived of the most of the water previously combined with it, while that below consists of the water which has dissolved the carbonate, and appears a dense oily-looking fluid.   The alcohol is decanted, or drawn off with a syphon, and more of the hot carbonate is added till it is no longer moistened.   All the water having been removed in this manner, the liquid is then to be distilled with a gentle heat, to separate it from a small portion of potassa which it usually acquires from the salt employed.   Nearly half a pound of the carbonate is required for every pint of rectified spirit of wine.

1916. Other substances are occasionally employed to separate the water from the alcohol, as lime, baryta, and the chloride of calcium.   Very strong alcohol may also be procured by suspending a bladder full of spirit of wine in the air ; the water passes through the coats of the bladder and evaporates from its surface, while the alcohol is retained.   When several gallons of alcohol are to be freed from water so as to procure it in a more concentrated state, though it may not be required in the form of absolute alcohol, this is frequently done by distilling it after mixing it with common salt.

1917. Professor Graham's process for preparing absolute alcohol may be easily conducted by those who have an air-pump.   A shallow glass or earthen basin is filled with quicklime in coarse powder or small fragments, and another nearly full of spirit of wine put over it.   They are then placed on the plate of the air-pump, and the air is exhausted till the liquor appears as if it were beginning to boil.   Both the water and alcohol evaporate at first, and the watery vapour is absorbed by the lime, which does not

affect the vapour of the alcohol. But water does not remain in combination with alcohol, unless covered by an atmosphere of its own vapour ; and as this is condensed by the lime as speedily as it is formed, the water continues to evaporate till it is completely removed, which usually requires three or four days, while the alcohol is prevented from evaporating by the pressure of its own vapour. Alcohol of specific gravity .796 may be procured in this manner.

1918. Absolute alcohol is a transparent and colourless liquid, having a fragrant odour, and a hot pungent taste. It is not only lighter, but also much more volatile than water ; when its specific gravity is 810°, it boils at 173°.5. Mr Walker exposed it to a temperature of — 91°, and more recently, by the spontaneous evaporation of liquefied carbonic acid gas, it has been exposed to a temperature of — 162°, and even to lower temperatures, without being congealed, though, when combined with carbonic acid it may be easily rendered solid. Rectified spirit of wine has been frozen, it is affirmed, by the rapid evaporation of sulphurous acid.

1919. Alcohol burns with a pale blue lambent flame (yellow if the alcohol be diluted with water), and every 23.24 parts consume 48 of oxygen. The products of the combustion are water and carbonic acid. A number of salts when mixed or dissolved in it impart a particular colour to the flame, particularly the hydrochlorate of strontia and the hydrochlorate of copper, the former communicating a deep red colour, and the latter rendering it of a fine green. With a great number of substances it combines in definite proportions, as Prof. Graham pointed out, forming a peculiar class of compounds, which he has termed Alcoates. It is decomposed by potassium and sodium, which attract oxygen from it, and disengage hydrogen gas.

1920. The quantity of alcohol in spirituous liquids may be ascertained by adding hot carbonate of potassa to them in the manner already mentioned, after precipitating the colouring and mucilaginous matters by dropping into them a strong solution of the acetate of lead, or agitating them with the protoxide of lead in fine powder. By operating in this manner, Mr Brande proved that alcohol really exists in fermented liquors, and is not formed, as had been affirmed, by a reaction taking place between their elements when heat is applied. A table of the results of Mr

Brande's experiments, and of the quantity of real alcohol in a variety of wines and other fermented liquors, is published in his Manual of Chemistry.

1921. Alcohol and water combine in every proportion, condensation, and an evolution of heat usually accompanying the combination. This may be easily seen by filling up with alcohol a tube 10 or 12 inches long and already half full of water, and inverting it repeatedly, that they may be mixed together, after closing the tube accurately with the thumb or finger. Thenard found, that when alcohol of the specific gravity of 0.9707 is mixed with an equal quantity of pure water, instead of any condensation taking place, they occupy a larger volume after they have combined than before. With an equal weight of water, alcohol forms what is usually called *Proof Spirit*, the specific gravity of which is 0.917. The *Proof Spirit* generally used for pharmaceutical purposes is weaker, having a specific gravity of 0.930, and containing 44 per cent. of real alcohol. The following table by Lowitz shews the quantity of real alcohol in diluted alcohol at different densities, and will be found useful in making experiments with this liquid.

Lowitz's Table, shewing the quantity of absolute alcohol in 100 *parts of spirit at different densities.*

Specific gravity at 60.	Alcohol in 100 parts.	Specific gravity at 60.	Alcohol in 100 parts.	Specific gravity at 60.	Alcohol in 100 parts.	Specific gravity at 60.	Alcohol in 100 parts.	Specific gravity at 60.	Alcohol in 100 parts.
0.796	100	0.848	80	0.896	60	0.939	40	0.974	20
0.798	99	0.851	79	0.898	59	0.941	39	0.975	19
0.801	98	0.853	78	0.900	58	0.943	38	0.977	18
0.804	97	0.855	77	0.902	57	0.945	37	0.978	17
0.807	96	0.857	76	0.904	56	0.947	36	0.979	16
0.809	95	0.860	75	0.906	55	0.949	35	0.981	15
0.812	94	0.863	74	0.908	54	0.951	34	0.982	14
0.815	93	0.865	73	0.910	53	0.953	33	0.984	13
0.817	92	0.867	72	0.912	52	0.955	32	0.986	12
0.820	91	0.870	71	0.915	51	0.957	31	0.987	11
0.822	90	0.872	70	0.917	50	0.958	30	0.988	10
0.825	89	0.874	69	0.920	49	0.960	29	0.989	9
0.827	88	0.878	68	0.922	48	0.962	28	0.990	8
0.830	87	0.879	67	0.924	47	0.963	27	0.991	7
0.832	86	0.881	66	0.926	46	0.965	26	0.992	6
0.835	85	0.883	65	0.928	45	0.967	25		
0.838	84	0.886	64	0.930	44	0.968	24		
0.840	83	0.889	63	0.933	43	0.970	23		
0.843	82	0.891	62	0.835	42	0.972	22		
0.846	81	0.893	61	0.637	41	0.973	21		

Alcohol is seldom prepared for commercial purposes with a less specific gravity than .830.

1922. The annexed table, by Tralles, extracted from Dr Ure's Dictionary, is an important addition to the history of alcohol, exhibiting *the bulk* of absolute alcohol in spirit of various specific gravities (sp. gr. of water being 1000), in the same manner as the preceding table shews the amount of spirit by weight.

Alcohol in 100 measures of spirit.	Specific gravity at 60° Fahr.	Alcohol in 100 measures of spirit.	Specific gravity at 60° Fahr.	Alcohol in 100 measures of spirit.	Specific gravity at 60° Fahr.	Alcohol in 100 measures of spirit.	Specific gravity at 60° Fahr.
1	9976	26	9689	51.	9315	76	8739
2	9961	27	9679	52	9295	77	8712
3	9947	28	9668	53	9275	78	8685
4	9933	29	9657	54	9254	79	8658
5	9919	30	9646	55	9234	80	8631
6	9906	31	9634	56	9213	81	8603
7	9893	32	9622	57	9192	82	8575
8	9881	33	9609	58	9170	83	8547
9	9869	34	9596	59	9148	84	8518
10	9857	35	9583	60	9126	85	8488
11	9845	36	9570	61	9104	86	8458
12	9834	37	9556	62	9082	87	8428
13	9823	38	9541	63	9059	88	8397
14	9812	39	9526	64	9036	89	8365
15	9802	40	9510	65	9013	90	8332
16	9791	41	9494	66	8989	91	8299
17	9781	42	9478	67	8965	92	8265
18	9771	43	9461	68	8941	93	8230
19	9761	44	9444	69	8917	94	8194
20	9751	45	9427	70	8892	95	8157
21	9741	46	9409	71	8867	96	8118
22	9731	47	9391	72	8842	97	8077
23	9720	48.	9373	73	8817	98	8034
24	9710	49	9354	74	8791	99	7988
25	9700	50	9335	75	8765	100	7939

1923. Alcohol is an agent that is constantly employed in the laboratory for affording a steady and powerful heat during its combustion, and in a great number of operations, where it is used as a solvent, or to afford peculiar combinations by the reaction of its elements with other substances. It is particularly useful in dissolving resins, camphor, volatile oils, vegetable acids and alkalis, and many salts and other substances which are insoluble in water, enabling us to separate them from other bodies with which they may be mixed or combined. From the large quantity of hydrogen and carbon which it contains, it has been

occasionally employed to deoxidate some compounds, and from the rapidity with which it evaporates, it is sometimes used to produce cold.

1924. Alcohol, in the condition in which it is prepared at first from any fermented fluid, is usually associated with variable quantities of different volatile oils, according to the source from which it is procured. Thus, the fermented infusion of malt gives *whisky* by distillation. The fermented solution of molasses produces *Rum.* The fermented juice of the grape affords *Brandy.*

1925. The oily matter in all these is frequently in considerable quantity, so as to impart a bluish opalescence to the liquid on mingling them with water, as the oil is less soluble in diluted spirit. Numerous processes are resorted to in order to remove this oil where the quantity is excessive, and sometimes it is entirely removed, so as to produce what is familiarly termed a *Silent Spirit,* as, when the oil is withdrawn, there is no odour to indicate the materials from which it may have been prepared. By distilling any spirit charged with volatile oil, after mixing it with caustic potassa, it will be observed to be very different in its odour in consequence of the action of the potassa upon the volatile oil. In distilleries, the oil is observed to be particularly abundant in the first products, which have been termed the *foreshot;* it is also found in considerable quantity in the last portions that are distilled, which are usually termed *feints.* On the large scale, the oily matter is usually removed by charcoal obtained from light wood, or animal charcoal, which absorbs it when kept in contact with the spirit for a considerable time.

ETHERS.

1926. A variety of products may be obtained by the action of the different acids on alcohol, which have received the generic appellation of *Ethers,* but differ considerably in their properties, according to the nature of the acids by whose action they have been formed.

Few subjects have attracted more attention of late years than the theory of the production of ethers, and from the variety of opinions entertained as to the mode in which the elements are associated, and the varied nomenclature that has

been introduced accordingly, the student cannot be too careful, in the first place, in examining the leading views as to the constitution of sulphuric ether, perhaps the most important of this class of combinations, which will enable him to proceed with comparative facility in tracing the history of the other combinations which belong to this class. The following brief explanation will assist him in this examination.

1927. ETHERINE is the name now given to quadrocarbureted hydrogen, being regarded by many as the base of most ethereal compounds. *Ethule* is the name given by Kane, Berzelius, and Liebig, to a compound of hydrogen and etherine, which they consider the base of ethers. It may be named more specifically *Hydruret of Etherine.* Its symbol is $H + 4 HC$. Sulphuric ether accordingly may be regarded as an *oxide of ethule*, this compound containing oxygen, carbon, and hydrogen, in the proportions in which they constitute one eq. of water and four of hydruret of carbon.

The following diagram represents this view more minutely :

Fig. 231.

Materials.		Products.

Oxygen.................8------------9 Water.

Ethule
- Hydrogen ...1
- Hydrogen . .1
- Hydrogen ...1
- Hydrogen ...1
- Hydrogen ...1
- Carbon ...6.12 ------- 7.12 Hydruret of Carbon
- Carbon ...6.12 ------- 7.12 Hydruret of Carbon
- Carbon ...6.12 ------- 7.12 Hydruret of Carbon
- Carbon ...6.12 ------- 7.12 Hydruret of Carbon

Etherine 28.48.
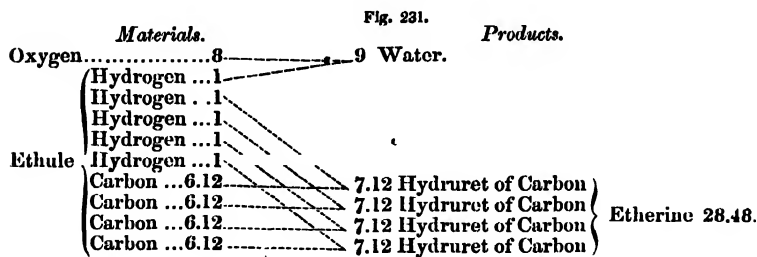
Thus sulphuric ether may be termed a compound of

                                                                    Symbols.
Oxygen + 4 Carbon + 5 Hydrogen   .   .   . OC^4H^5

Or it may be named—

Hydrate of etherine   .   .   .   .   .   . $\cdot H + (4 HC)$
Oxide of ethule   .   .   .   .   .   . $O + H^5C^4$

1928. In the preparation of ethers four varieties of action may be pointed out.

I. The ether may be produced by the decomposition of alcohol, and composed solely of elements derived from this substance, those of the acid being entirely excluded from the new

compound. Common ether, called also sulphuric ether, affords an example of this kind of action.

II. The acid may contribute by its decomposition a new element to the alcohol, as it is converted into ether. Thus, hyponitrous ether contains nitrogen, which is derived from the nitric or nitrous acid used in its preparation.

III. The ether may be produced by the production of sulphuric or common ether (OC^4H^5), in the first instance, this ether combining with an equivalent of undecomposed acid to produce the new ether.

IV. Lastly, some elementary substances united with ethule produce new ethers, as in chloric ether. By studying the composition of the following ethereal compounds, these views will be more distinctly understood.

1.	Common Ether (sulphuric),	.	.	.	.	OC^4H^5.
2.	Hyponitrous Ether,	.	.	.	.	$!N + OC^4H^5$.
3.	Acetic Ether,	.	.	.	.	$O^3C^4H + OC^4H^5$.
4.	Oxalic Ether,	.	.	.	.	$!C^2 + OC^4H^5$.
5.	Chloric Ether,	.	.	.	.	$Cl^2 + C^4H^5$.

1929. In preparing other ethers, the alcohol requires to be mingled, not only with the acid that gives the more peculiar character of the ether to be produced, but also with sulphuric, phosphoric, or some other acid, to determine the production of the more common ether, which may be regarded as the base of many of these combinations.

SULPHURIC ETHER.

Symb. OC^4H^5, or $\cdot H + 4HC$. *Eq. by W.* $37.48 = O.8 + C.24.48 + H.5$; *or water* 9 $+$ *olefiant gas* 28.48. *Its sp. gr. is* .720. *It boils at* 98° *in the open air, and in vacuo at* —40°. *When reduced in its temperature to* —47° *it becomes solid and assumes a crystalline texture. Equivalent by volume* □. *Sp. gr. of vapour* 2.589 ; *Weight of* 100 *cubic inches* 80.28 *grs.*

1930. To prepare sulphuric ether, equal weights of sulphuric acid and alcohol are exposed to heat in a plain glass-retort, pouring in the alcohol first and then the acid by a long glass funnel, Fig. 55, page 34; and adjusting the retort in a sand-

bath already heated to the temperature of 200°, in the manner shewn in Fig. 77, page 60. The acid and the alcohol should be well· mixed by shaking them together in the retort, when, the temperature rises considerably. The receiver should be tubulated, to convey away the atmospheric air, and any other gaseous products that may be formed towards the close of the operation.

Fig. 232.
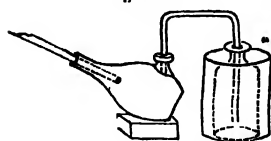
The annexed figure shews the receiver, the neck of which should fit closely to the neck of the retort ; and the joint should be rendered tight by tying round it a piece of linen or cotton cloth spread over with paste made of flour. The bent tube fixed to the tubulure of the receiver should be made to pass into a second receiver, or to dip into a bottle in the manner represented, which is kept cold by placing it in a jar or basin with water or ice ; the tube must not fit tightly · to the neck of the bottle, but allow any gas that may come over to be freely disengaged. The first receiver should have a piece of linen or cotton cloth tied round it, that it may be more easily kept cold ; ice or snow should always be used when it can be procured.

1931. The distillation is generally continued till a quantity of liquid has come over equal to one-half of the alcohol employed. More ether is obtained when it is kept constantly boiling at a particular temperature, than if the heat be irregularly applied. The retort should not be filled more than half full, and great attention must be paid to the heat applied during the whole of the operation, as the mixture is apt to boil over when urged with too strong a fire. By adding half the quantity of alcohol employed at first, an additional quantity of ether may be obtained, and this may be repeated again ; the acid afterwards becomes so diluted, however, that it is unable to produce any more.

1932. The ether that condenses in the receiver is never obtained pure at first, being always mixed with a little alcohol that distils over unaltered, and some sulphurous acid produced by the decomposition of part of the sulphuric acid. To remove these, it is mixed with potassa, taking five or six grains for every ounce of alcohol employed, and distilled again from a retort with a very gentle heat till five or six sevenths shall have passed over ; the potassa retains the sulphurous acid, along with some

water and alcohol. To separate the alcohol completely, the product of the second distillation may be shaken with about three-fourths of its bulk of water, which combines with all the alcohol and a little ether, the most of the ether separating from it in a short time and floating above. It is then decanted, and kept in bottles with ground glass stopples.

1933. Prepared in this manner, it is not in a state of absolute purity, being combined with a small quantity of water. When required free from this, it must be mingled intimately with chloride of calcium, which retains the water, and then be redistilled.

1934. In preparing ether on the small scale, an ounce or two of alcohol with as much sulphuric acid by weight, will be sufficient to shew the process, condensing the product in a common flask.

1935. The theory of the action has already been adverted to, being essentially similar to what takes place in the first stage of the process for the preparation of olefiant gas. (See the diagram representing the decomposition of alcohol, &c. page 154). In the present instance, however, a much smaller quantity of sulphuric acid being used, less alcohol is decomposed, every 37.48 parts of ether that are procured being formed by the combination of 14.24 parts of olefiant gas and 23.24 of alcohol.

1936. In the preceding description of the preparation of ether, one or two circumstances have been omitted, which it is now necessary to state. When aqueous sulphuric acid is mingled with alcohol, Mr Hennel shewed that an immediate action ensues, during which, part of the acid unites with alcohol and forms a compound termed SULPHOVINIC ACID. That part of the acid is in a peculiar state of combination, is proved by the action of baryta, which precipitates only a portion of that which is employed, the remainder in combination with alcohol forming *Sulphovinate of Baryta.*

1937. Again, Mitscherlich, who has examined this action with great care, has shewn the extreme importance of attending to the temperature employed, and has also proved, by a very interesting series of experiments, that indefinite quantities of alcohol can be converted into ether by the action of a limited quantity of aqueous sulphuric acid, if it be associated with water and spirit, so as to boil uniformly at the same temperature ; the

alcohol employed then leaving nothing with the acid. The alcohol is supplied in a constant stream ; so that the acid appears to act as an intermediate agent, by which the alcohol is resolved into water and ether, both these being distilled and continually separated as the alcohol is supplied.

1938. For this purpose, aqueous sulphuric acid, to 100 of which about 20 parts of water have been added, is heated to 340°, and alcohol being now introduced in a slender continuous stream into the retort containing the acid, the heat must be so adjusted as to distil without alteration of temperature an amount of water and ether equal to the alcohol used. The alcohol is introduced into the liquid acid by a glass-tube passing through the tubulure of the retort (or flask) which may be employed. (See Miscellaneous Apparatus.) Should the temperature vary as the operation advances, the stream of alcohol must be varied accordingly. If it should exceed 340°, more alcohol must be introduced, but if it should fall below that point, the stream of alcohol must be diminished.

1939. When the operation is conducted in this manner, two fluids may be observed in the receiver. The upper fluid consists of ether associated with a portion of water and alcohol, and the other of water holding some alcohol and ether in solution. These must be separated from each other, and the former purified from alcohol and water in the manner formerly described.

1940. Water can dissolve only a small quantity of ether, but alcohol and ether combine in every proportion. Ether is very inflammable, and burns with a much more copious and richer flame than alcohol ; the products of its combustion are water and carbonic acid. A few drops put into a detonating bottle full of oxygen gas, which is immediately corked, speedily diffuse themselves through the gas, and form an inflammable mixture that detonates violently on bringing a lighted match to the mouth of the bottle. This is an experiment that should be performed with a very small and strong bottle, as detonating bottles that have not been injured by any other explosive mixtures are frequently broken by this. When transmitted through a red-hot tube, ether is decomposed, and gives the same products as alcohol.

1941. From the rapidity with which ether evaporates at

natural temperatures, it is often used to produce an intense degree of cold. If a small quantity be poured into a jar, which is immediately covered with a tray, it speedily evaporates, and on applying a lighted candle to the mouth of the jar, it is found to be full of an inflammable vapour. If a larger quantity of ether be put into an open jar, and a coil of thin platinum-wire heated to redness in a spirit-lamp be suspended over it at a particular distance, which is easily found on trying the experiment, instead of becoming cold, it remains red hot till the whole of the ether is consumed. The platinum being a slow conductor of caloric, it does not part with its excess of heat very rapidly, and coming in contact with the vapour of ether and air in the jar, the high temperature which it is at causes a slow combustion to take place, by which a sufficient degree of heat is produced to maintain it in a state of incandescence. A considerable quantity of acetic acid is produced during the slow combustion of ether, when effected by the action of platinum.

1942. Sulphuric ether is not capable of dissolving so many substances as alcohol ; still, however, it is often found useful in separating or extracting principles that are insoluble in alcohol or water, more especially in vegetable chemistry. It combines with ammonia, camphor, resins, volatile oils, sulphur, phosphorus, and chloride of gold, but has little or no action on the fixed alkalis, earths, common metallic oxides, and the greater number of the salts.

HYPONITROUS (CALLED ALSO NITROUS OR NITRIC) ETHER.

Symb. $\overset{\cdot\cdot}{N} + OC^4H^5$. *Boils at* 70°. *Sp. gr. about* .886.

1943. In all experiments with nitric acid and alcohol, great care must be taken not to mix a large quantity of acid with the alcohol at once, as the gaseous products that are immediately produced are apt to throw out the whole of the mixture with explosive violence. Though a small quantity of acid may be added to a large quantity of alcohol without any particular action being observed, a small quantity of alcohol cannot be mixed with a large quantity of acid without being completely decomposed, as the particles of the alcohol are surrounded by the

L l

acid on every side, which affords oxygen more readily to the inflammable elements that enter into its composition. To observe this, all that is necessary is to pour a few drops of the acid into the alcohol, and then of the alcohol into the acid, when the appearances described will be noticed.

1944. The best method of preparing hyponitrous ether is by mixing equal weights of alcohol and the strong fuming acid, prepared by distillation from two parts by weight of sulphuric acid with three of nitre. The acid reacts on the alcohol, and in a day or two it is converted into ether, which floats on the top of the remaining liquid, and may be easily removed by a small syphon. Pure nitrous acid, prepared by distillation from the nitrate of lead, would do still better, but it is not so easily obtained. Two or three ounces of alcohol will be sufficient to shew the nature of the process ; the alcohol is put into a bottle first, and small quantities of the acid are poured into it at a time by a funnel with a long stem, which passes to the bottom of the bottle, mixing them thoroughly after each addition of acid, and then placing the bottle in cold water to prevent any violent reaction taking place. A dram or two of the acid may be added every quarter of an hour in this manner, till it is all mixed with the alcohol. The bottle should be provided with a conical stopple to allow the gas that accumulates in it to be disengaged ; it is forced up in the same manner as the stopple in Nooth's apparatus, already described, and returns to its place when the excess of gas has passed by it.

1945. Instead of employing the acid and alcohol alone, the alcohol may be introduced first, and an equal bulk of water poured below it, by a long funnel leading the water to the bottom of the phial in which the operation is to be conducted. The acid is then introduced in the same manner with much caution below the water.   The acid and alcohol ultimately react slowly, through the medium of the water, which attracts both.

1946. Other methods for the preparation of nitric ether have been proposed. The Dublin College directs the alcohol to be mixed with sulphuric acid in a flask, and the mixture to be poured over bruised nitre in a retort. The proportions they recommend are nearly 865 of nitre, 1345 of sulphuric acid, and 725 of alcohol, by weight ; the sulphuric acid is much more than sufficient to decompose the nitre, and a smaller quantity might

perhaps be used with advantage. The retort must be placed in a basin of cold water to prevent the action becoming too violent, and it should not be filled more than a third full of nitre. I have seldom found it necessary in repeating this process at ordinary temperatures, to apply any heat to commence the action, as is usually recommended. The sulphuric acid combines with the potassa, and the nitric acid evolved, acting on the alcohol in its nascent state, produces the ether. It must be condensed in a large tubulated receiver kept very cold ; when a large quantity is prepared, a second tubulated receiver should be connected with it, and the gaseous products allowed to escape by another bent tube. The first method of preparing nitric ether will be found preferable, however, as the reaction is apt to become very turbulent when this process is adopted, though every precaution be taken to prevent it.

1947. Hyponitrous ether always contains a little acid as it is procured at first, which may be removed by mixing it with a little potassa or lime, and then distilling it. It has a very pale lemon-yellow colour, a pleasant smell similar to that of apples, and a strong penetrating taste. It is heavier and more volatile than sulphuric ether, burns with a lambent flame, and soon becomes acid on being kept. When it is purified by distillation, the operation should always be carried on with a very gentle heat, as it is decomposed when distilled quickly at a higher temperature.

1948. Hyponitrous ether consists of carbon, oxygen, hydrogen, and nitrogen, and is now generally regarded as a compound of hyponitrous acid and sulphuric ether. Dr Bird has lately examined the varied products that are formed during the production of hyponitrous ether, and has shewn that they consist of *aldehyde, oxalhydric acid, acetic acid,* and *oxalic acid.* They may be considered as so many results of the oxygenating action of nitric acid on alcohol in different degrees. From numerous experiments, he infers—

1. During the action of nitric acid on alcohol, no oxalic acid is formed as long as nitrous ether alone distils over.

2. That aldehyde is not produced, at least in any appreciable quantity, until oxalic acid appears in the retort and the production of nitrous ether nearly ceases.

3. That during the preparation of nitrous ether in the cold.

acetic acid is abundantly produced, and appears to replace oxalhydric acid formed when heat is employed.   Dr Bird also noticed that in crystallizing the residual fluid in the retort, the first crop of oxalic acid crystals that appeared were of the ordinary form ; but that those produced by subsequent evaporation were in pearly scales.   •

Spirit of Hyponitrous Ether.
•

1949. The SPIRIT OF HYPONITROUS ETHER is familiarly termed *Spirit of Nitrous or of Nitric Ether*, *or Sweet Spirit of Nitre*, and consists of hyponitrous ether and alcohol.   It is prepared by mixing nitric or nitrous acid with a larger quantity of alcohol than is used in the process for preparing nitric ether, and distilling the mixture in a glass-retort.   The Edinburgh College directs one pound of their nitrous acid (191) to be mixed with three of alcohol, and distilled with a heat not exceeding 180°, till a quantity of liquid has been obtained equal to the alcohol employed.   The distillation may be commenced whenever the materials have been mixed ; the precautions already pointed out must be attended to, and the receiver kept cold in the usual manner.

1950. This compound is often prepared in large quantities by merely mingling hyponitrous ether and alcohol.

1951, ACETIC ETHER is composed of one equivalent of sulphuric ether and one of acetic acid.   It may be prepared by the action of aqueous sulphuric acid upon a mixture of alcohol and acetate of potassa, being separated by distillation from the sulphate of potassa formed at the same time.   Liebig has procured it by distillation from the following materials mixed together,— four and a half parts of alcohol, five of aqueous sulphuric acid, and sixteen of acetate of lead carefully freed from water of crystallization.   Sulphate of lead remains in the retort.

Many other ethereal compounds have been prepared of late. They are usually procured by processes similar to those which have been described.

1952. SULPHOVINIC ACID (called also ALTHIONIC* ACID) is formed when aqueous sulphuric acid and alcohol are mingled at natural temperatures. It was considered till lately a compound of sulphuric acid and hydruret of carbon, but is now regarded as a compound of sulphuric acid and alcohol $(Symb. \ \ddot{:}S + OC^2H^3)$. Many have doubled the equivalent of this compound, from theoretical considerations, and represent it by $2\ddot{:}S + 2 \ (OC^2H^3)$. To obtain it in a pure form, the mixture of alcohol and sulphuric acid is neutralized by a solution of baryta; sulphate of baryta falls, and sulphovinate of baryta remains in solution. The solution of the sulphovinate is then decomposed by sulphuric acid, which precipitates the baryta, and leaves the sulphovinic acid in solution. Sulphovinic acid combines with the salifiable bases, forming salts, few of which have been minutely examined. The sulphovinates of potassa and soda crystallize with facility.

1953. OIL OF WINE, or SULPHATE OF ETHER, is the name given to a compound of sulphuric acid and ether, which was formerly regarded as a compound of sulphuric acid and hydruret of carbon. $(Symb. \ \ddot{:}S + OC^4H^5)$. It is prepared according to the formula of the London College in the following manner:—Mix carefully two pounds of rectified spirit with four pounds of aqueous sulphuric acid. Heat the mixture in a retort till it becomes black and produces a black froth, allowing it then to cool by removing it immediately from the heat. It now presents a light fluid, resting uppermost, which must be carefully separated from another and heavier liquid upon which it floats. The lighter fluid must then be exposed to the air for 10 or 20 hours, that any ether associated with it may be separated by evaporating; and after agitating it with a dilute solution of potassa, to remove any sulphurous acid, the oil of wine subsides in a pure form. It has a yellowish colour, a fragrant and penetrating odour, and a bitter taste. Water does not dissolve it, but it is soluble in alcohol and in ether.

1954. ALDEHYDE† $(Symb. \ OC^2H^2. \ Sp. \ gr. \ .790. \ Boils \ at \ 71°)$. This liquid has been prepared in the following manner:—The vapour of ether is passed through a red-hot glass-tube filled with fragments of glass, when it is resolved into aldehyde, water,

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* This term is derived from the words alcohol and θειον (sulphur).

† The term Aldehyde is derived from the first syllables of the words *alcohol* and *dehydrogenatus*, signifying alcohol deprived of part of its hydrogen.

inflammable gases, and charcoal. These being introduced into
ether maintained at a very low temperature, the aldehyde is
condensed; and dry ammoniacal gas being at the same time in-
troduced into the ether, it is also condensed, and a compound of
aldehyde and ammonia is formed, which is gradually deposited
in transparent crystals. To separate the aldehyde, two parts
of the crystals are mixed with an equal weight of water, and
put into a retort with three parts of aqueous sulphuric acid,
previously diluted with four parts of water. Heat must then
be applied with great care by a water bath, which must not be
elevated in its temperature to 212°; the aldehyde rises and is
condensed in the receiver. The water associated with it must
be separated by another distillation, after mingling it with the
chloride of calcium. Heat is evolved when the aqueous alde-
hyde and the chloride of calcium are mixed together, so that
the retort must be cooled, and the mixture made with much
care, that the aldehyde may not be dissipated.

1955. Aldehyde is an inflammable liquid, and has a very pe-
netrating and peculiar odour; its vapour, even when diluted
with much air, affects respiration powerfully, suspending mo-
mentarily, in some individuals, the power of continuing it.
Water, alcohol, and ether combine with it in all proportions.
Exposed to air, confined in a glass or other vessel, it absorbs
oxygen and produces acetic acid; when spongy platinum is
placed over it, the production of the acetic acid is much acce-
lerated. Exposed freely to the air, a crystalline compound is
ultimately formed, which is fusible, volatile, and inflammable.
With chlorine and bromine, it forms, according to Leibig, Chlo-
ral and Bromal; it has also been considered that hydrochloric
and hydrobromic acids are produced.

1956. Aldehyde acts powerfully on oxide of silver, reducing
it in part to the metallic condition by withdrawing oxygen, form-
ing ALDEHYDIC ACID, and combining with the remaining oxide
of silver. For this purpose, it is usually mingled with water,
heated gently with the oxide, and then subjected quickly to a
boiling temperature. The new compound may be decomposed
by baryta, which precipitates the oxide of silver in solution; but
if the solution be now boiled in contact with the oxide of silver,
the oxide is reduced, its oxygen is transferred to the aldehydic
acid, and it is now converted into acetate of baryta. Oxide of

silver has been proposed as a test of aldehyde, from the facility with which it is acted upon by this substance, and reduced to the metallic form.

1957. ALDEHYDIC ACID (*Symb.* $O^3C^4H^4$), being composed of one eq. of oxygen and two of aldehyde (one of aldehyde, if it be represented by doubling the number previously adopted). This acid is particularly distinguished by the facility with which it reduces metals from a number of metallic solutions, more particularly those of gold, silver, mercury, and copper, becoming acetic acid as it removes oxygen from the oxide which it decomposes.

1958. ALDEHYDEN is the name given by Liebig to a supposed compound of four eqs. of carbon and three of hydrogen, which has not hitherto been insulated. RESIN OF ALDEHYDE is the resinous looking matter that is produced, when aqueous aldehyde is heated with potassa, collecting in the form of a thin film upon the surface of the liquid.

1959. CHLORAL (*Symb.* $O^4C^9Cl^6$, *or* $O^2C^4HCl^3$?). This compound was discovered by Leibig, being formed by the action of chlorine upon alcohol. The process is tedious, principally on account of the very large quantity of gaseous chlorine required in the operation, which must be freed from moisture and hydrochloric acid before it is brought in contact with the alcohol. The chlorine is gradually absorbed, and produces hydrochloric acid by combining with hydrogen derived from the alcohol. At first the alcohol must be kept cold; the hydrochloric acid is expelled afterwards by heating the solution. When the reaction has ceased, the chloral is purified first by the action of aqueous sulphuric acid, which separates water, and subsequently by distillation from quicklime in powder, which retains any acid. Chloral, though a compound of great interest in a theoretical point of view, has not hitherto been applied to any practical purpose of importance. Many details as to its preparation, which require attention, will be found in the Ann. de Chim. et de Phys., or in Thomson's Organic Chemistry.

1960. Chloral is a transparent, colourless, and almost tasteless liquid, having an oily appearance, and a penetrating odour. It combines with water, sulphur, bromine, and iodine ; and is decomposed when heated with different earths and metals, metallic chlorides being formed. INSOLUBLE CHLORAL is the

name given to a new compound, produced by the action of aqueous sulphuric acid with chloral at natural temperatures, when they are left in contact for 24 hours.

1961. Bromal is prepared by the action of bromine upon alcohol, and is similar in its properties to chloral.

1962. Acetal is produced by the slow action of alcohol on the oxygen of the air, assisted by introducing over it in small cups or watch-glasses, small portions of spongy platinum. It is purified by distillation from carbonate of lime and chloride of calcium. *Symb.* OC^8H^9.

1963. Mercaptan, or Hydruret of Mercaptum. *Symb.* $H + S^2C^4H^5$. The name of this substance is derived from the powerful action which it has with the peroxide (binoxide) of mercury. It is a colourless and volatile liquid; it dissolves sparingly in water, but freely in alcohol and in ether. It was procured by Zeise, on distilling sulphovinate of baryta mixed with hydrosulphate of baryta; sulphate of baryta is left in the retort. It is not pure as it is obtained at first; by the action of the peroxide of mercury upon it, 2 eqs. of water and 1 of bimercapturet of mercury are formed. From this substance it is most easily prepared by the action of hydrosulphuric acid, 2 eqs. of this compound reacting with 1 of the bimercapturet of mercury, as shewn in the following diagram.

Fig. 233.

2 Eqs. of Hydro-sulphuric Acid.	Hydrogen 1			62.68 Mercaptan.
	Hydrogen 1			62.68 Mercaptan.
	Sulphur 16.1			
	Sulphur 16.1			
1 Eq. of Bimer-capturet of Mercury.	Mercaptum 61.68			
	Mercaptum 61.68			
	Mercury 203			235.2 Bisulphuret of Merc.

1964. Mercaptum has not been procured in an insulated form. Its symbol, calculated from the composition of mercaptan, is $S^2C^4H^5$.

1965. Dr Gregory has prepared lately a new compound, similar to mercaptan, but much more volatile; he procured it by a similar process, substituting pyroxilic spirit for alcohol, and then proceeding as in the preparation of mercaptan.

1966. Xanthic acid is composed of 1 eq. of alcohol and 2 eqs. of the bisulphuret of carbon. *Symb.* $2(S^2C) + OC^2H^3$. Of late,

however, it has been affirmed that the bisulphuret of carbon is combined with ether in xanthic acid:

1967. Xanthogen is the term applied by Zeise to the bisulphuret of carbon, being considered as the base of xanthic acid. These terms are derived from the yellow colour presented by several of the xanthates (ξανθος, yellow). Xanthogen, when mixed intimately with alcohol and potassa, produces xanthate of potassa.

ORDER V.—LIGNIN, GUM, SUGAR, STARCH, &c.

1. LIGNIN, OR WOODY FIBRE.

1968. This is the most abundant of vegetable principles, constituting upwards of 90 per cent. of the different kinds of wood. It is obtained pure, after saw-dust has been acted on by alcohol, water, and diluted acids. It is insoluble in water. Nitric acid produces with it oxalic and other acids. By strong sulphuric acid, it is decomposed, carbon being deposited, while sulphurous acid and water are produced. With weak sulphuric acid a saccharine matter may be formed. It is the great source of charcoal or carbon, as it is used for all ordinary purposes. It produces, when decomposed without access of air, a great variety of products, viz. inflammable gases, acetic acid, pyroxilic spirit, water, kreosote, and other oily products, along with resinous matters, mingled together at first in the form of tar.

2. GUM.

1969. Gum-arabic is soluble in water, hot or cold, but insoluble in alcohol and in ether. Dissolve some gum-arabic in water, by reducing it to powder and triturating it with this fluid in a mortar ; the solution is usually called Mucilage.

1970. Pour a solution of gum in water into alcohol ; the water

combines with the alcohol, and the gum is precipitated. All in-fusions and decoctions containing a quantity of this principle in solution, give a precipitate with alcohol, when it is mixed with them in sufficient quantity.

1971. Add a solution of oxalic acid to a solution of gum in water; the acid unites with the small quantity of lime which gum always contains, forming oxalate of lime, which is separated in the form of a white precipitate.

1972. Expose a portion of gum-arabic to the flame of the blowpipe till nothing remains but a white or greyish-white ash; this is composed principally of carbonate of lime. Dissolve it in diluted hydrochloric acid in a test-tube, and precipitate oxalate of lime from the solution by oxalate of ammonia.

1973. Take a strong solution of gum, and mix with it a satu-rated solution of borax. In certain proportions, the solutions, when stirred together, become quite thick and gelatinous; and, if the jelly be allowed to dry in a glass vessel, it often breaks it to pieces, adhering firmly to it as it contracts.

1974. Add a solution of gum-arabic to a solution of the dit-acetate of lead; the gum is immediately precipitated in combi-nation with part of the oxide of lead. Gum is precipitated from its solution by some other salts, as the persulphate of iron and bipernitrate of mercury.

1975. Add a solution of silicated potassa to a solution of gum-arabic; a precipitate is thrown down immediately, which has been regarded as a compound of the lime which the gum contains and silica. The pure alkalis form soluble compounds with gum.

1976. Mix some powdered gum with strong sulphuric or nitric acid. It will soon be completely decomposed. The sulphuric acid causes a deposition of carbon, but produces sugar if di-luted; and the nitric acid converts it into mucic or into oxalic acid, if a large quantity be employed.

1977. ARABINE is the term applied to the pure gum of gum-arabic, and has been regarded as a compound of 12 eqs. of car-bon, 11 of oxygen, and 11 of hydrogen. *Symb.* $O^{11}C^{12}H^{11}$. If this be correct, it is the same in composition as common sugar.

. 1978. Alcohol decomposes common gum-arabic, removing, when boiled with this substance, a vegetable salt containing

lime, a compound resembling wax, and chlorides of calcium and potassium.

1979. GUM-SENEGAL is similar in its properties to gum-arabic.

1980. The MUCILAGE OF LINSEED, extracted by the action of hot water upon linseed, is considered to differ essentially from a solution of gum in water, though resembling it in several respects.

1981. BASSORIN is found in gum bassora and in gum tragacanth, mixed with arabine and other substances. It is left when the gum is dissolved in cold water, and has been converted by long boiling into a compound resembling gum-arabic or arabine.

1982. CERASIN is the name applied to the gum of the cherry tree, which, though insoluble in cold water, appears to be converted into a matter similar to arabine by boiling in water.

3. SUGAR.

1983. The composition of sugar has been variously estimated of late years, but it appears now to be very generally admitted that it is a compound, in its dry state, of 12 eqs. of carbon, 10 of hydrogen, and 10 of oxygen, as is represented in the following table.

		Symb.
Dry Sugar,	. . . .	$O^{10}C^{12}H^{10}$.
Common Sugar,	. . . . . .	$O^{11}C^{12}H^{11}$.
Diabetic Sugar,	. . . . . .	$O^{13}C^{12}H^{13}$.
Starch Sugar,	. . . . . .	$O^{14}C^{12}H^{14}$.

Thus, all these varieties of sugar may be regarded as compounds of anhydrous sugar and water in various proportions.

1984. Dissolve sugar in hot water till a strong syrup is obtained, and put the solution aside in a warm place. Crystals of sugar (candied sugar) are slowly deposited. Large crystals of sugar may be obtained by dissolving it in alcohol, and setting aside the solution for some time. Four parts of hot alcohol take up about one of sugar.

1985. Rub two pieces of white sugar briskly on one another in the dark; a green phosphorescent light is seen at the point of contact.

1986. Mix equal weights of sugar and chlorate of potassa, and touch the mixture with a glass-rod dipped in sulphuric acid. A rapid deflagration immediately takes place, a small quantity of sulphate of potassa is formed, and chlorous acid (peroxide of chlorine) is disengaged (559), the heat produced being sufficient to inflame the mixture, while the chlorate of potassa affords oxygen to support the combustion of the sugar.

1987. Mingle intimately, in a Wedgwood's mortar, 10 grains of sulphuret of antimony with 20 of white sugar. Mix this on paper with 60 grains of chlorate of potassa, previously reduced to a fine powder. This mixture may be deflagrated by sulphuric acid in the same manner as the preceding.

1988. Sugar decomposes strong nitric acid, a large quantity of fumes of nitrous acid being disengaged, while it is converted into oxalic acid (1638).

1989. Digest some slaked lime in fine powder in a solution of sugar in water. A considerable quantity is dissolved, and may be precipitated again by oxalic, tartaric, and carbonic acids.

1990. Sugar, like tartaric acid, has the property of preventing oxide of iron and a few other metallic oxides from being precipitated from their solutions by some of those reagents that usually throw them down ; it possesses this property, however, only when it has been boiled along with the solution of the metallic salt. Sugar has also the property of partially deoxidating a number of the metallic oxides when they are heated together in solution.

1991. A number of vegetable and animal substances may be converted into sugar by the action of dilute sulphuric acid, such as wood, gum, starch, linen, glue, &c.

Mix 1 part by weight of sulphuric acid with 12 of starch and 100 of water, expose the mixture to a moderate heat for two or three days, digesting it in a sand-bath, or in any other convenient situation, and stirring it frequently. An earthen jug or evaporating basin is generally employed. The liquid is then to be neutralized with chalk, and filtered, and the clear liquid is to be evaporated till it acquires a syrupy consistence, after which it may be set aside to crystallize. Crystals of sugar will be procured.

4. Starch or Fecula.

1992. A small quantity of starch may be easily prepared from potatoes, by diffusing through a large quantity of water the pulpy mass that is obtained on grating them, and allowing it to remain at rest. In this process, the saccharine and mucilaginous matters that exist in the potatoes are dissolved by the water. The starch being heavier than water, and insoluble in cold water, is deposited at the bottom in the form of a fine powder, and the fibrous matter floats above. It may be purified by washing it repeatedly with cold water, and pouring off the supernatant liquid. On the large scale, the supernatant liquid is not poured off till it begins to ferment, a larger quantity of starch being procured in this manner, and the fibrous matter being more easily separated. Common starch is prepared from wheat by a similar process.

1993. Starch is easily distinguished from gum and sugar by its insolubility in cold water, and by forming a jelly with hot water. Its solution in water decomposes the solutions of several metallic salts, but gives no precipitate with silicated potassa. Its action on iodine, which is the most delicate test of this substance, has been already stated (632-3-4).

1994. Starch has been considered, till of late years, a proximate principle, incapable of farther subdivision without being resolved into its ultimate elements. Raspail, however, has shewn that it consists of two distinct principles, viz. Amidine,* the matter that constitutes the little vesicle which forms the outer part of every minute grain or particle of starch, and Amidin, the matter contained in the solution which this vesicle encloses. By boiling potato starch in 100 parts of water, the amidin may be obtained in solution ; the amidine is insoluble in cold or boiling water, but when starch is boiled in water, the vesicle which it composes gradually swells and bursts, allowing the soluble amidin to escape.

1995. A similar change is probably effected during the process by which starch is converted into British Gum. For this

* This term has been applied frequently to the soluble matter of starch, or amidin; the terms given above, however, appear to be more generally adopted at present.

purpose the starch is roasted, or exposed with extreme care to a moderate heat. It then becomes more miscible with and soluble in water, though it does not appear to present a matter very homogeneous in its qualities and composition.

5. Hordein.

1996. Hordein has been prepared by different processes. It is usually procured from barley-meal made into a stiff paste with water, when the hordein and starch may be removed by the action of water allowed to drop upon it. By boiling this mixture in water acidulated with sulphuric acid, all the starch is ultimately dissolved and the hordein is left. Hordein is not applied in a pure form to any important purpose. During the malting of barley, it is converted into starch.

6. Diastase.

1997. To prepare diastase, macerate ground malt in cold water, separate by pressure the liquid thus procured, and filter it. Heat it to 158° and filter again. To the solution thus procured add alcohol, which precipitates the diastase. Dissolve it repeatedly in water, and precipitate it again by alcohol, that it may be obtained in a pure form.

1998. The property by which this substance is peculiarly distinguished is, that, at a temperature of about 160°, it separates the *amidine* or *envelope* from the *amidin* or soluble part of starch, the former floating upon the surface of the solution in which it may be suspended, or being precipitated. It is from this circumstance that it received its name, which is derived from a Greek word signifying to separate. It is by the action of diastase that starch is converted into sugar during the process of malting, one part of diastase being sufficient to render soluble the amidin in 2000 parts of starch. In solution it is rapidly decomposed, and if exposed to a boiling temperature, it loses its power of acting upon amidin.

7. DEXTRINE.

1999. This term has been applied to a peculiar amylaceous principle, extracted or prepared by the action of water upon a mixture of 1 part of malt with 10 of flour. 4 or 5 parts of water are used with 1 of flour. The water is heated in the first place to 86° or 90°, and the ground malt then added. The temperature is then gradually increased to 140°, when the flour may be put in. The mixture is then maintained as nearly as possible at a temperature of about 160°, till it becomes comparatively clear and fluid, when it is heated as quickly as possible to 212°. The suspended impurities are then allowed to separate, by leaving the whole at rest. The clear liquid containing the dextrine may then be drawn off and concentrated by evaporation, so as to afford either a gelatinous mass, or a dry cake, which may be reduced to powder. It may be used in either form as an article of food.

8. GLUTEN?

2000. Gluten may be obtained from wheat-flour, by making it into a stiff paste with water, and washing it in a linen cloth or bag with a large quantity of this fluid, as long as any white powder passes through the interstices of the cloth. The gum and sugar are dissolved by the water, the starch is carried away in suspension in the form of a white powder, and the gluten remains in the cloth.

2001. Gluten is very tenacious and ductile. It is insoluble in water, and when moist is speedily decomposed from the reaction of its elements. It is considered the most nutritious part of wheat-flour, and contains nitrogen in addition to the usual elements of vegetable matter.

2002. Gliadine and Zimome, the two principles of which gluten is composed, according to M. Taddy, may be separated by rubbing gluten with successive portions of alcohol in a mortar as long as the fluid becomes milky on diluting it with water. The alcohol dissolves the gliadine, and leaves the zimome.

2003. Zimome is particularly distinguished by the bluish-green

colour which it assumes when moistened with water and tritu-
rated with powdered gum-guaiac. The same colour appears when
wheat-flour or gluten is treated in a similar manner with gum-
guaiac, the colour being deeper in proportion to the quantity of
gluten which the flour contains.

9. TAN, TANNIN, or TANNIC ACID.

Symb. $O^{12}C^{18}H^8$.   *Eq.* 214.16.

2004. Tannin exists in a great number of vegetable substances,
and is usually associated with gallic acid. Pelouze has given
the following process for its preparation. Obstruct a very deep
tube or funnel with a little cotton, and over this place gall-nuts
reduced to a fine powder, covering them afterwards with sul-
phuric ether containing a little water. The ether is now allowed
to filter slowly through the galls, and collected in a flask or bottle
placed below. Two fluids are observed in the vessel with the
filtered liquid, the upper consisting principally of ether, and the
lower or heavier fluid containing the tannin in solution. This
denser liquid is purified by agitating it repeatedly with ether,
and affords the tannin when evaporated spontaneously, the tannin
increasing considerably in bulk, as it loses the water and ether
that were in combination with it.

2005. Mr Hatchett has pointed out that tannin may be formed
artificially by digesting charcoal, and some other vegetable sub-
stances containing a large quantity of this element, in nitric
acid ; some, however, suppose that this is merely a compound of
charcoal and nitric acid.

2006. Tannin is distinguished by its astringent taste, by pre-
cipitating a number of metallic oxides from their solutions, and
forming, with solutions containing gelatine, a copious precipi-
tate, similar in its composition to leather, which is a compound
of tannin and gelatine. Tannin is very soluble in alcohol, hot
water, and in ether containing a little water. It effervesces
with alkaline carbonates, and hence has been called Tannic Acid.
If any gallic acid be mingled with it, the tannin may be entirely
removed by a portion of skin (gelatine) steeped in it for some
time, after which, any gallic acid may be detected in the remain-
ing solution by a persalt of iron.

VI.—COLOURING MATTER.

2007. **To** prepare the coloured test-papers which have been so frequently referred to in this work, a red cabbage must in the first place be cut into slices, and infused with a pint or two of boiling water. The liquid is then to be decanted from the vegetable matter that remains, and concentrated by evaporation, till it is reduced to five or six ounces by measure Then pour it into a flat plate or basin, and steep in it pieces of unsized paper (common printing-paper does very well) ; taking care to moisten every one thoroughly, by drawing them backwards and forwards several times through the liquid before they are laid one above another. In half an hour they may be taken out to dry, and hung on a piece of cord drawn tight between two nails on the opposite sides of a room, where they will not be exposed to dust or acid fumes. The paper may be cut into pieces about the size of an octavo page before they are immersed in the solution, and each of them may be divided across into thirty or forty slips. They should be put into a tin case, or some other convenient vessel, that they may be always at hand, as they are continually required in a great variety of operations. A sufficient quantity may be made at once in this manner to serve for a year or two, even where a great number of experiments are performed.

2008. Paper dyed blue with the colouring matter of the cabbage is used for indicating the presence of acids and alkalis, being turned red by the former and green by the latter. It is sufficiently delicate for all ordinary experiments, and is preferable to litmus-paper, which is not affected by alkalis, unless previously reddened by an acid, when the original blue is restored.

2009. When the colouring matter of the cabbage is required in solution, it may be easily obtained by infusion in water. It begins to pass into a state of putrefaction in a few days, however, causing a very disagreeable smell, and the colour fades at the same time. The concentrated solution may be kept for a long time, when put in bottles which are completely filled with

it, after mixing every ounce or two with half a drachm of sulphuric acid. Dr Faraday states that it may be preserved in this manner for a year.

2010. LITMUS and TURMERIC test-papers may be prepared by a similar process. The litmus may be reduced to fine powder and boiled with water to procure a solution fit for the purpose. Turmeric-water again may be obtained sufficiently strong by pouring boiling water over this substance in powder. Litmus-paper is used as a test for the presence of acids, which immediately redden it, and as a test for alkalis, when it has been previously reddened by an acid. Turmeric-paper again is rendered of a reddish-brown colour by alkalis and alkaline earths, but is not affected by the acids ; it may be used, however, as a test of acids when it has been previously turned brown by an alkali, the acid combining with the alkali and restoring its original yellow colour. It cannot be relied on, however, as a test for the presence of alkalis in compound solutions containing different kinds of saline matter, a number of compound salts and other substances affecting it in the same manner as these bodies, as Dr Faraday has pointed out.

2011. The colouring matter of Brazil-wood is often employed in preparing test-papers. A decoction is made for this purpose, in which the paper is steeped in the usual manner. The colour is in general brightened in its tint by acids, when they are not sufficiently concentrated to destroy it ; hydrofluoric acid, however, gives a yellow tint. Alkalis produce a violet or purplish colour.

2012. Put a number of flowers into a vase of chlorine gas. The colour gradually disappears.

2013. Take three glasses with water, and add a little blue cabbage infusion to each. Leave one as it is, redden another with a drop of acid, and turn the third to a green by a little alkali. Then add chlorine water to all of them. The tint in each is destroyed, if a sufficient quantity of chlorine be added.

2014. Take some blue cabbage infusion, and dilute it largely with water. Then add it, in small successive quantities, to a table-spoonful of chlorine water put into a deep jar. The first portions added are instantly decolorized ; but when the chlorine is exhausted in its bleaching properties, having taken hydrogen from the water or colouring matter, it is converted into hydro-

chloric acid; and succeeding portions of the vegetable blue, as they are added, are not bleached, but reddened.

2015. Put a number of pieces of calico, dyed with different kinds of vegetable colouring matter, into a solution of chlorine in water. The colour soon disappears ; but those adjective colours which have been put on, without any basis or mordant,* are destroyed before any of the others.

2016. Repeat this experiment with a solution of chloride of lime instead of chlorine water.

2017. To another portion of the chloride of lime solution mixed with various coloured stuffs, add a small portion of acid, that the chlorine may be brought more effectually in action upon the colouring matter.

2018. Prepare a dilute solution of litmus in water, mix six or eight ounces with a table-spoonful of animal charcoal, and boil for some time. The colouring matter is entirely removed or decomposed, and the solution becomes colourless.

2019. Add a solution of sulphurous acid to a dilute solution of blue infusion of cabbage. The colour immediately disappears. If, however, any sulphuric acid be associated with the sulphurous acid, it overcomes the action of the latter, and the colouring matter is reddened instead of being blanched.* Add now small portions of ammonia in succession till the sulphuric acid is neutralized, when the red tint is discharged.

2020. The colourless liquid may now be rendered of a brilliant green, by adding a little ammonia in excess. It may then be changed to a red by adding sulphuric acid in excess, or again rendered colourless by neutralizing the sulphuric acid.

2021. Put one or two roses into the upper part of a glass apparatus, such as is used in the combustion of iron in oxygen (1001, page 291), securing them with a string, and leaving out the cork. Take a small earthen-dish (the lower part of a broken crucible does very well), put a few grains of sulphur into it, and kindle it with a red-hot iron wire. The dish may then be put within the glass-jar, elevating it a little at one side that the air may enter freely. The sulphurous acid produced by the combustion of the sulphur rises in the jar and blanches the roses ; some roses are blanched in a few seconds, while others resist the action of the sulphurous acid a long time.

* See Mordant.

2022. Bleach some purple grape hyacinths in the same manner.

2023. Hold a few purple grape hyacinths for a short time in a jar into which a little strong hydrochloric acid has been thrown. The colouring matter soon assumes a vivid red tint.

2024. Proceed in the same manner with a few more, putting a little strong ammonia into the jar instead of hydrochloric acid; they immediately become of a beautiful green colour.

2025. Repeat the two last experiments with the grape hyacinth after it has been bleached by sulphurous acid. It is acted upon in the same manner as if it had not been bleached.

2026. Make a solution of litmus in water, and try the action of acids and alkalis upon it. The acids, it will be observed, render the solution red, but the alkalis do not turn it to a green. They restore the original tint, however, when added to a solution of the litmus reddened by an acid.

2027. Proceed in the same manner with turmeric. The acids do not change the yellow colour, but the alkalis render it brown. The acids added to the brown-coloured compound neutralize the alkali, and restore the original yellow tint.

2028. Pour hot water on the common red cabbage cut into small pieces. A fine blue-coloured liquid is procured, which is rendered red by acids and green by alkalis.

2029. Put a small quantity of a strong solution of the hydrochlorate of tin into seven or eight ounces of a solution of litmus, and add a solution of potassa as long as it produces any precipitate. The potassa combines with hydrochloric acid, forming hydrochlorate of potassa which remains in solution, and the oxide of tin, uniting with the litmus, forms an insoluble compound which is immediately precipitated. It is in this manner that the pigments called *Lakes* are usually prepared.

2030. Make a similar experiment with solutions of alum (sulphate of alumina and potassa) and litmus : on adding the solution of potassa, the alkali combines with the sulphuric acid previously in combination with the alumina, which is thrown down in combination with the litmus.

As the oxide of tin and alumina can combine only with a certain quantity of colouring matter, if the whole of the litmus be not precipitated at first, and the liquid be not left transparent nd colourless, by adding an additional quantity of hydrochlo-

rate of tin or alum to the solution, and precipitating as before by potassa, all of it may be thrown down.

2031. Make a strong solution of cochineal in water, and precipitate the colouring matter in combination with alumina or oxide of tin, by a solution of potassa. A rich coloured lake is immediately precipitated similar to *Carmine*.

2032. Acetate of alumina is generally preferred to alum in processes where alumina is to be separated in combination with colouring matter, as the acetic acid that is disengaged is not so liable to react upon cloth or colouring matter as sulphuric acid, which often proves troublesome when alum is used. It may be easily obtained by adding a solution of the acetate of lead to a solution of alum as long as any precipitation takes place, filtering the liquid to separate the sulphate of lead that is thrown down, and concentrating the solution by evaporation. In this condition, acetate of potassa is also contained in the solution.

2033. Digest some indigo reduced to powder for an hour or two in sulphuric acid, till a solution is obtained. Dilute the solution with a large quantity of water, and put a piece of silk, linen, or cotton into it, taking it out immediately and allowing it to dry. Part of the indigo combines chemically with the cloth, which is soon dyed blue, the shade being more or less deep according to the strength of the solution. Solutions of this kind being very caustic, other modes have been resorted to for dissolving indigo, by which it is subjected to the influence of some deoxidating agent.

2034. Dissolve some sulphuret of arsenic in a hot solution of potassa, and digest indigo reduced to a fine powder in the liquid. The metallic sulphuret attracts oxygen from the indigo, which will become of a green colour, and be immediately dissolved. Put a piece of cloth into the solution, then take it out and allow it to dry, exposing it freely to the air. The cloth combines immediately with a portion of deoxidated indigo, and appears of a green colour when first taken out of the liquid. It soon attracts oxygen from the air, however, the indigo recovering its original colour; and it is in this manner that cloth is usually dyed blue by indigo. Green sulphate of iron dissolved in water, and mixed with lime, which precipitates oxide of iron, is extensively used as a solvent of indigo, the oxide of iron deoxidating it, and rendering it soluble. INDIGOGENE is the name applied to deoxidated indigo.

2035. Expose some indigo to heat over a chauffer in a glass-vessel; it is sublimed at the temperature of 550°, a reddish violet-coloured vapour being formed, which bears some resemblance in its colour to iodine vapour, and condenses in minute crystalline grains. It forms what is more especially termed INDIGO BLUE, which is procured in its purest form by digesting it successively with diluted sulphuric acid, potassa, and alcohol. INDIGO RED and INDIGO BROWN are the terms applied to two other principles contained in indigo, but they are not so important as indigo blue. It is insoluble in water and alkaline solutions; boiling alcohol dissolves a minute quantity. Strong sulphuric acid is its proper solvent. When the solution is decomposed by diluting it with water, a portion of the indigo is deposited in combination with water, forming a hydrated compound called PHENECIN, or indigo purple. Berzelius has also described two new compound acids, INDIGO SULPHURIC ACID and INDIGO HYPOSULPHURIC ACID, which are formed by the action of sulphuric acid on indigo blue.

2036. INDIGOTIC ACID is procured by boiling indigo in dilute nitric acid.

2037. CARBOZOTIC ACID (*Symb.* $O^{15}C^{15}N^3$) is a more important compound, and is formed by the action of strong nitric acid upon indigo. It is prepared by Liebig's process in the following manner:—Indigo, in small fragments, is heated with ten times its weight of nitric acid. It evolves much nitrous acid vapour, and is dissolved. The solution is boiled, and nitric acid added as long as it produces any disengagement of red vapours. On cooling, a large quantity of semi-transparent yellow crystals is deposited. These are washed with cold water, and then dissolved by boiling in water. Any oily looking matter on the surface of the solution must be removed by filtering paper laid upon it. Yellow crystals are obtained on filtering and cooling. Dissolve these in boiling water, neutralize by carbonate of potassa, and purify by repeated crystallization, the carbazotate of potassa thus formed. Dissolve this salt in boiling water and add diluted sulphuric acid as the solution cools. Crystals of carbazotic acid, of a yellow colour, are deposited.

2038. Carbazotic acid is fusible, and may be volatilized without decomposition. It inflames when heated powerfully, and leaves a carbonaceous residuum. It is sparingly soluble in cold

water, but much more soluble in boiling water, ether, and alcohol. Its solution has a bitter taste. It combines with the salifiable bases, forming salts which are decomposed by heat. Of these some deflagrate ; and others explode with violence if confined at the same time.

2039. Numerous other colouring matters have been used for the extraction of particular colouring principles, but few of them are so important or have been so minutely examined as those obtained from indigo.

2040. In a paper read lately before the Royal Society of Edinburgh, by Dr Hope, he adduced numerous experiments to prove that there are two varieties of vegetable colorable matter, which are acted upon by acids and alkalis in producing red, yellow, or green tints. The one he has termed Erythrogen, as it produces a red colour with acids ; the other, he has denominated Xanthogen,* from its affording a yellow compound with alkalis.

2041. These two principles occur together in red and blue flowers, and in the leaves of a few plants, presenting the former of these tints. Litmus abounds in erythrogen, but has no xanthogen. The term CHROMOGEN is applied to colourless compounds which produce varied tints when acted upon by acids, alkalis, or other agents. Some white flowers contain chromogen which becomes red or green when acted on by acids and alkalis, and there is reason to believe that there may be many different kinds of chromogen.

2042. CHLOROPHYLE is the name usually applied to the green colouring matter of plants, but this term has been applied, and also the terms CHROMULE and CHROMOGEN, in a variety of different senses. The green colouring matter of plants is now regarded as a peculiar principle, which becomes yellow and red during autumn by the absorption of oxygen and the production of acid, so that it may often be rendered green again by the action of an alkali which neutralizes the acid.

2043. Some colouring matters can be communicated to cloth, paper, or other substances, by merely dissolving them, and bring-

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* These terms have been applied to substances of a very different character by Bizio and Zeise, the former having employed the word Erythrogen to designate a peculiar animal matter, and the latter has termed bisulphuret of carbon, xanthogen, as the base of xanthic acid.

ing their solutions in contact with the matter to be impregnated with them. This depends upon the strength of the attraction they exert towards the substances with which they combine ; and if they remain permanently in combination after this process, not being easily removed by any ordinary exposure to which they may be subjected, these are usually termed SUBSTANTIVE COLOURS or COLOURING MATTERS. Of these indigo is an excellent example.

2044. ADJECTIVE colouring matters, on the other hand, have a comparatively feeble attraction for cloth, but they have a considerable affinity for earthy or metallic oxides, whether they be brought in contact with them in solution, or after they have been combined with the cloth to be dyed. These substances, which are used to fix such colouring matters on cloth, are usually termed MORDANTS or BASES, and the most important are alumina, oxides of tin, and oxides of iron, which are much employed by the calico-printer.

2045. If an acid paste be applied by a carved wooden block or copper cylinder to any part of a piece of cloth to be dyed, it prevents the mordant from attaching itself at that place when the colouring matter enters into combination, and thus a white pattern may easily be developed there, while the rest of the cloth remains of the tint communicated to it. Citric acid is much used for this purpose.

2046. To study the general method of proceeding, mix a little of the solution of the sulphate of iron with paste, spread it very thin upon cloth, and take up a little by pressing upon it any stamp or block of wood with a pattern cut upon it, which may be applied many successive times to different parts of the cloth if required ; any plain piece of wood will do, if no pattern can be procured. Dry it, immerse it in a little aqueous ammonia diluted with much water ; the acid is removed, and the pattern appears on the cloth in the form of oxide of iron. Run a little water upon it, and pour upon one portion the infusion of galls. A black pattern is now seen upon a white ground. Put another portion into a basin of water, to which a few drops of ferrocyanate of potassa in solution and aqueous nitric acid have been added. A blue pattern is now observed.

2047. For RED DYES, Brazil-wood, bar wood, lac, archil, madder, peach-wood, and cochineal, are the principal colouring matters

in common use. The cochineal is procured from an insect, which is believed to derive its colouring matter from a particular vegetable principle upon which it feeds. Oxide of manganese and catechu are much used for browns.

2048. YELLOW DYES are procured principally from saffron, hiccory, quercitron bark, Persian berries, turmeric, fustic, and annatto. A buff is obtained with peroxide of iron.

2049. BLACK DYES are made with the same materials as writing ink, as gallic acid, tannin, and peroxide of iron ; also with madder, logwood, and iron.

2050. BLUE DYES are commonly prepared with Prussian blue or indigo.

2051. By combining red, yellow, blue, or black colouring matters with each other, mechanically or chemically, all other tints may be produced, and by varying the strength of the colouring matter, or the strength of the mordant, different shades of the same colour may be had.

GERMINATION AND VEGETATION.

2052. SOILS. The soil serves not merely as a support for the plant, but is also the medium by which it is in general supplied with a large proportion of food, and is often the principal source of aliment, especially when it abounds with decomposed vegetable and animal matters. Silica, alumina, and carbonate of lime are the principal earthy ingredients in fertile soils, and the first of these, silica, is generally the most abundant, varying from fifty to eighty per cent., and part being usually in the form of sand, while the rest is in a more minute state of division. The earthy matter of the soil also enters into the composition of the plant in minute, but variable proportions, as is proved by the nature of the ashes procured after incineration. A soil is not absolutely necessary for the growth of all plants, as some have been kept for years suspended in the air, where moisture and other substances derived from the air have alone contributed to its support. Sulphur, pounded glass, and metals in a fine state of division, have sometimes been substituted for ordinary soils, and still vegetation has been . found

to continue, these being the channel by which other matters have been supplied.

Some earthy substances promote the growth of particular plants, and may be detected in them.   Thus sulphate of lime is found in clover, silica is secreted in the joints of the bamboo, constituting tabasheer, and is observed also in the ashes of different kinds of grain along with lime and alumina.*

2053. All plants impoverish soils by drawing off the nutritious matter which they may contain.   But different plants do not act with equal force in this respect, nor in the same manner.   Neither in the debris which they leave do they contribute the same amount of nourishment.   Hence a rotation or succession of crops produces a greater return on numerous soils than the cultivation of a single species.

2054. When a seed GERMINATES, the germ or substance of the future plant is nourished by the decomposition of the rest of the seed, oxygen being absorbed, carbonic acid evolved, and sugar being formed.   A temperature from 55° to 80° is most favourable to germination ; moisture must be present, but light retards this operation.   By steeping seeds in chlorine water when they do not germinate with facility, they are made to germinate more readily, in consequence of the chlorine removing hydrogen from the water and thereby liberating oxygen.

2055. In the process of MALTING, barley is made to germinate by the action of air, heat, and moisture, and the process is then checked.

1. It is *steeped* in water, swelling as it is absorbed.

2. It is *couched,* or laid in heaps to the depth of thirty inches for nearly twenty-eight or thirty hours, when it gradually becomes warmer.

3. It is *floored,* or separated into smaller portions which are frequently burned to prevent the germination proceeding irregularly, and the production of any inequality of temperature.

Lastly, it is kiln-dryed, or exposed to a considerable heat, by which much moisture is expelled, and a deep or light colour communicated to the malt according to the temperature applied.

2056. In malting, the plumula, called also *acrospire,* is usually allowed to extend till it is prolonged to the opposite end of the seed, when the process is arrested.   From the following

analysis of barley and malt by Proust, the changes induced during malting may be observed, the principal effect depending upon the production of starch and sugar from hordein.

	100 parts of Barley contain	100 parts of Malt contain
Hordein,	55	12
Starch,	32	56
Gluten,	3	1
Sugar,	6	15
Gum,	4	15
Resin	1	1

2057. The germ is thus supplied in the living plant with more soluble nutritious matter than it previously had, and the plumula ascends to form the body of the plant, while the radicle descends and constitutes the roots. Considerable loss of weight attends germination; according to Dr Thomson, it is equal to one-fifth part.

2058. VEGETATION includes all those processes by which the growth of the plant is sustained after germination. By ABSORPTION from the air and from the soil it is supplied with food. By CIRCULATION, the sap conveys nourishment and support to every part of the plant. By respiration and transpiration the sap is so changed in its qualities that the materials it contains may be said to have undergone a kind of digestion; and by secretion, all those proximate principles are elaborated of which each plant is composed.

2059. Light appears to have great influence on vegetables, especially in respiration, as, when it is powerful, they decompose carbonic acid, absorbing carbon and liberating oxygen, while in the dark, they produce carbonic acid principally, and consume oxygen. An atmosphere with 10 per cent. of carbonic acid, which is said to be fatal to many plants in the shade, contributes much to their nourishment and support in a bright sunshine. The respiration of plants is effected through their leaves, though it is not improbable that other portions of the surface may also act upon the air, but in a less powerful manner. No oxygen is liberated except when the plant is supplied with carbonic acid.

The amount of evaporation and absorption of moisture by different plants, varies to a great extent. Some are described which absorb and emit moisture so rapidly as to take up and give off their weight of water in a single day.

PART. II.—ANIMAL SUBSTANCES.

2060. Animal substances contain in general carbon, oxygen, hydrogen, and nitrogen, along with small and variable proportions of earthy, saline, or metallic compounds, more especially of iron, which may be traced in most animal matters. Earthy compounds are rarely found in them in large quantity, except in bones, or in those cases where they may be deposited from morbid action, as in calculous diseases.

2061. Animal is still more prone to decomposition than vegetable matter, from the presence of an additional element, nitrogen, giving rise to a complicated structure and a more nicely balanced affinity, which is more easily subverted. Carbonic acid, carbureted hydrogen, and ammoniacal gases, are the principal products of the decomposition of animal substances, along with variable proportions of animal matters in solution, and small quantities of hydrosulphuric and phosphureted hydrogen gases. Watery vapour escapes continually along with these, during decomposition, but if moisture be not freely supplied by the external air, the process of decomposition is arrested, and the soft solids gradually become hard and stiff, resembling perhaps in their mechanical properties stiff leather more than any other substance.

2062. Among the animal proximate principles, several have been noticed bearing a considerable resemblance to those of the same class derived from the vegetable kingdom, more especially the animal oils and fats, which are similar in their general chemical relations to the fixed vegetable oils.

2063. Expose any ordinary animal matter to heat in an open fire, it is gradually consumed, depositing at times, however, a carbonaceous crust difficult of incineration. Heat this crust, should it not be consumed by the action of the air, with a small portion of nitre in an iron or earthen crucible. It deflagrates ra-

pidly with the nitre, and produces carbonate of potassa. On dissolving this, any insoluble earthy or metallic compounds contained in the animal matter, may be procured by themselves.

2064. Expose some muscular fibre to a running stream of water for several weeks, taking care to exclude it from the action of the air. It is decomposed, and an imperfect kind of fat is produced, supposed to consist of the original fatty matter mixed with the fibrine, combined, however, with ammonia produced by the decomposition of the fibrine. In this condition it is usually termed *adipocire*.

2065. If animal matters, to be used as food, be put into tin cases, these being filled up afterwards with any sauce so as to exclude the air as much as possible, and then put into boiling water for a number of hours immediately after they shall have been introduced into the case, all the oxygen of any included air is consumed, the albuminous matters are coagulated, and the tin cases having been previously soldered carefully, so as to close completely every aperture, the matters thus treated resist decomposition, and can be preserved unaltered for a very long period under ordinary circumstances.

2066. Fibrine, albumen, and gelatine, constitute the more abundant proximate principles of which the soft solids are composed, their composition per cent., omitting fractions, is given in the following table.

	Carbon.	Hydrogen.	Nitrogen.	Oxygen.
Fibrine,	53	7	19	19
Albumen,	50	7	15	26
Gelatine,	47	7	16	27

1. BONE AND SOFT SOLIDS.

2067. Expose a few bones to heat in an open fire. All the animal matter is consumed, and the earthy and saline matters remain, presenting the original form of the bone.

2068. Macerate a bone in hydrochloric acid, diluted with twice its bulk of water. In a few days, the earthy matter is dissolved by the acid, and the animal matter is left, presenting also, as in the preceding case, the original form of the bone. Add to the liquid obtained in this manner, potassa in solution

till the hydrochloric acid is neutralized. The phosphate of lime dissolved by the acid is precipitated.

2069. Expose fragments of bone to a red heat in a crucible, allowing the gaseous matters evolved to escape, but preventing any access to the bone by a cover carefully luted to the crucible. When gas ceases to be evolved, or when nothing appears where the gas is permitted to escape but a pale blue flame, remove the crucible from the fire, allow it to cool, still carefully excluding the air; and when cold, remove the cover. The earthy matter of the bone, being covered with charcoal derived from the decomposed animal matter, appears quite black. The mass that is thus procured is usually termed ANIMAL CHARCOAL or IVORY BLACK, and when reduced to a coarse powder, may be used for all the purposes for which it has already been recommended, more especially for decolorizing solutions containing animal and vegetable colouring matter.

2070. Digest some animal charcoal in diluted hydrochloric acid; filter the solution, and wash the charcoal repeatedly with water. It is procured in this manner in a purer form, but it is not necessary for ordinary purposes to separate in this manner the earthy ingredients from the animal charcoal.

2071. The composition of bone varies very considerably at different periods of life, and even in different portions of the same bone a great diversity in the relative proportions of its constituent parts may be observed. In general, bone contains about 33 per cent. of animal matter, which is composed principally of gelatine. The composition of the earthy constituents of bone in 100 parts of common bone is stated in the following table.

	Parts.
Phosphate of lime, about	51
Carbonate of lime,	11
Fluoride of calcium,	2
Phosphate of magnesia,	1

Soda, chloride of sodium, and water, smaller portions. Silica, and alumina, sulphate of lime, and traces of oxides of iron and manganese.

2072. Expose bones to the action of high pressure steam (steam having a force equal to half an atmosphere over the usual pressure of the air is sufficient). The solution produced by the

action of the condensed steam with the animal matter forms the gelatine of bones extracted by the process recommended by D'Arcet. His experiments on this subject have been carried on with great success and to a great extent at Paris, producing gelatine very economically, and in a condition in which it may be applied with great advantage in the preparation of a number of different articles of food.

Composition of Miscellaneous Animal Solids.

2073. The TEETH are composed of the same ingredients as bone, with a much smaller proportion of animal matter. They are dissolved by diluted nitric acid. In the enamel, the phosphate of lime constitutes 78 per cent.

2074. The SHELLS of Crustaceous animals, the PEARL, MOTHER-OF-PEARL, and the shell of eggs, consist principally of carbonate of lime.

2075. HORNS, HOOFS, TENDONS, LIGAMENTS, MEMBRANES, the CUTICLE, and the TRUE SKIN, are composed principally of gelatine. Horns, membranes, and ligaments contain a portion of matter insoluble in water, and usually regarded as coagulated albumen.

2076. The MUSCLES are composed principally of fibrine, associated with albumen, gelatine, osmazome, fatty, and saline matter.

2077. In HAIR, WOOL, and FEATHERS, a peculiar matter has been detected, regarded, however, by some as approaching to coagulated albumen. Silica, sulphur, salts of manganese, and lime, have also been detected in them.

In the substance of the BRAIN and NERVES, albumen, fatty matters, and osmazome constitute the principal ingredients, which are associated there with a large quantity of water, amounting to about 80 per cent. Sulphur, phosphorus, and saline matters have also been detected.

2. FIBRINE.

2078. Fibrine may be easily procured in a pure form by pouring off the serum from coagulated blood, and washing the

crassamentum in a linen or cotton bag with a large quantity of water, till all the colouring matter and adhering serum is carried away. The fibrine remains, of a white colour with a tint of yellow, which is more apparent in some kinds of fibrine than in others. It may be obtained in a state of sufficient purity for all ordinary purposes, by cutting muscular fibre to small pieces, and washing it repeatedly with cold water.

2079. Fibrine may be easily converted into a fatty matter by the action of diluted nitric acid. Mix three ounces of nitric acid with one and a half times their weight of water, and expose the liquid to heat over a chauffer with three parts of muscular fibre. Nitrogen gas is disengaged, not mixed with any binoxide of nitrogen at first, and appearing to arise solely from the decomposition of fibrine. In a short time, however, the acid itself begins to be decomposed, a large quantity of fatty matter is formed, and binoxide of nitrogen and vapours of nitrous acid are evolved. The nitrogen disengaged in the first stage of the process may be collected, if required, by heating the mixture in a glass retort, the beak of which is introduced under the surface of water in a pneumatic trough with jars arranged in the usual manner.

2080. With sulphuric acid, a solution is procured, containing a peculiar white matter called LEUCINE; the sulphuric acid is separated from it by chalk, the solution of the leucine being then filtered and evaporated.

2081. Pour some concentrated acetic acid over fibrine in a Florence flask, and allow them to remain mixed together for some time; the fibrine gradually softens, and on exposing it to a gentle heat, it is dissolved, and a gelatinous mass is obtained, which is soluble in water. The fibrine appears, however, to be partially decomposed, as a little nitrogen gas is disengaged during the solution of the jelly in water.

2082. Put some fibrine into a solution of potassa or soda at ordinary temperatures, and allow them to remain mixed together. The fibrine is slowly dissolved, and may be precipitated again from the solution by neutralizing the alkali with an acid, but not precisely in its former condition.

3. ALBUMEN.

2083. Put a piece of blue test-paper into the white of an egg ; it soon turns green, the albumen and water, of which it is almost entirely composed, containing a portion of free soda. A similar experiment may be made with the serum of the blood, which also is composed principally of water and albumen with a little free soda.

2084. Albumen coagulated by heat, or by drying successive layers in the open air, resembles fibrine considerably, and can scarcely be distinguished from it by the action of tests. Berzelius states that it has no action on binoxide of nitrogen, but that fibrine produces a disengagement of oxygen.

2085. Expose some of the white of an egg or the serum of the blood to a temperature which need not exceed 160° ; in a short time it is converted into a firm coagulum.

2086. Mix some albumen with a considerable quantity of cold water, and expose it afterwards to heat ; the albumen is coagulated, and the water becomes opaque, even though the liquid should not contain more than $\frac{1}{1000}$th part of albumen.

2087. From the property which albumen has of being miscible with cold water, while it is coagulated by hot water, it is used in many chemical operations for clarifying saline solutions which do not coagulate it at natural temperatures. For this purpose, the albumen is added to the liquid to be clarified while cold, and on exposing it to heat, the albumen coagulates slowly as the temperature increases, forming a kind of network which envelopes the dust and any other extraneous matters which the liquid may contain, and collects as a scum at the surface which is easily removed. On the large scale, the fluid part of blood is much used for this purpose, the fibrine being separated as the blood is drawn, by stirring it briskly with a bundle of twigs before it coagulates.

2088. Put the white of an egg into a Florence flask, and pour an ounce or two of sulphuric acid upon it ; the albumen is immediately coagulated, and on applying a gentle heat, it is completely dissolved ; it is decomposed, however, at the same time, and the liquid assumes a very dark colour, having a purple tint. When the heat is very carefully applied, Dr Hope found that

N n

the liquid often becomes of a very beautiful red colour ; the circumstances necessary to insure the production of this fine tint in all cases have not been determined.

2089. Mix the white of an egg with a considerable quantity of water, and pour the liquid into a number of glasses ; then add to these, alcohol, dilute sulphuric acid, hydrochloric acid, nitric acid, a solution of ferrocyanate of potassa mixed with acetic acid, a solution of the bichloride of mercury, and a solution of the ditacetatê of lead.   The albumen is coagulated by acids and alcohol, and decomposes solutions of several metallic salts combining with the metallic oxide, and forming an insoluble compound which is precipitated.   With the bichloride of mercury, the precipitate that is thrown down was formerly regarded as a compound of the chloride of mercury and albumen. But various statements have been made of late upon this point, the precipitate having been regarded by some as a compound of peroxide of mercury and albumen, the peroxide being produced by the action of water and the bichloride.   Smaller quantities of albumen may be detected in this manner than in any other way, a single drop of a saturated solution of the bichloride rendering water turbid when it contains only a 2000dth part of albumen in solution.   An excess of albumen dissolves those precipitates which are compounds of an albumen and an oxide.

2090. Add an infusion of galls to a similar solution of albumen in water ; a copious precipitate is immediately thrown down, composed of albumen and tannin.

2091. Phosphoric and pyrophosphoric acids do not precipitate albumen, but the metaphosphoric acid coagulates it with facility.

4. Gelatine and Osmazome.

2092. Dissolve one part of dry gelatine in a hundred parts of hot water ; a liquid is obtained, which becomes a tremulous jelly when cold.

2093. Add an infusion of galls to a solution of gelatine in water ; a copious precipitate is immediately thrown down, composed of tannin and gelatine, and similar in its composition to leather. Pour boiling water upon it until its particles aggregate and se-

parate from the greater portion of the water. It presents a very peculiar appearance, is very soft, may be moulded into any shape, and drawn into long threads, or stretched into a thin membranous looking sheet. It soon becomes very brittle, losing all the elasticity it presents at first.

2094. Add a solution of the bichloride of mercury to a solution of gelatine and albumen as long as any precipitation takes place ; the albumen is precipitated, and the gelatine remains in solution ; it may be removed afterwards by a solution of tannin. If the tannin be added to the liquid containing the albumen and gelatine before precipitating the former by bichloride of mercury, both the albumen and the gelatine are thrown down in combination with it.

2095. For all ordinary experiments where gelatine is required, common glue will be found to do very well ; where it is necessary to have a purer gelatine, ISINGLASS should be employed. Glue is commonly procured by boiling animal substances in water, and evaporating the solution till it becomes sufficiently concentrated, fatty matters and other substances insoluble in water being separated. The gelatine of glue is accordingly never pure.

5. OSMAZOME.

2096. OSMAZOME is found associated with muscular fibre and other animal matters ; it is particularly distinguished by its solubility in water and alcohol at any temperature, and by not forming a gelatinous solid when its solution is evaporated. It is precipitated by infusion of galls. Osmazome is regarded as the matter which gives to broth its peculiar flavour.

6. BLOOD.

2097. The blood is a fluid which is usually of a red colour, circulating through the system in a complicated manner in the higher animals, when it passes from the extreme vessels in which it performs the various functions required in the living system to the right auricle of the heart, by which it is propelled into the

right ventricle. From the latter, it is conveyed to the lungs where it is subjected to the action of the air, returning now to the left auricle and subsequently to the left ventricle, by which it is propelled in endless succession throughout the whole system so long as life continues. It loses the bright colour it had acquired in the lungs, as it again 'reaches the extreme vessels where the working arteries, as they have been popularly termed, continue their functions, and assumes the dark tint of venous blood which is again renovated in the lungs, while the nourishment derived from the food and various products absorbed from the different tissues are equally conveyed to it during the progress of the circulation.   • -

2098. Examine a portion of newly drawn blood by the microscope. It is not homogeneous, but presents the appearance of a transparent fluid, in which red globules are seen suspended, being flattened, and not spherical, as the term globule is apt to indicate.

2099. These globules are of different sizes and forms in different animals. In man they have usually been regarded as having a diameter equal to the 1–5000dth to the 3000dth of an inch. They present the appearance of flattened disks, and have evidently an organized structure, consisting of a central nucleus with a red envelope. The annexed figures, from Muller's Physiology, represent the figure of the globules of blood from six different animals.

Fig. 233.
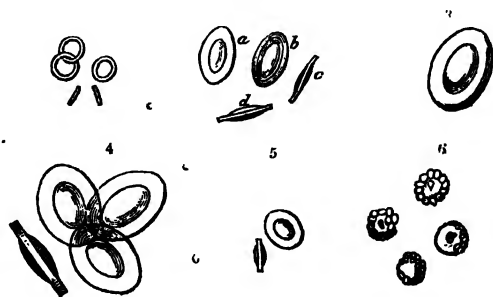
Fig. 1. Red particles of human blood. (Wagner.)

Fig. 2. Red particles of the blood of the common fowl; *a*, ordinary appearance when the flat surface is turned toward the

eye ; *b*, appearance which is sometimes presented by the particle when in the same position, and which suggests the idea of a furrow surrounding the central nucleus ; *c*, *d*, different appearances of the particles when seen edgeways.

Fig. 3. Red particles of the frog.

Fig. 4. ... of the squalus squatina. (Wagner.)

Fig. 5. ... of the lophius piscatorius. (Wagner.)

Fig. 6. Particles from the blood of the scorpion. (Wagner.)

2100. Collect some blood in vessels of different depths, and observe the variety in the manner in which it coagulates, according as it is received into deep or shallow vessels. The buffy coat, so often observed in blood taken during any inflammatory action, may be noticed frequently when the blood is received into a deep jar, depending upon the red particles subsiding through a portion of the coagulum ; it is always observed in the blood of horses. Dr Newbigging has shewn that the colour of the coagulum is affected in a remarkable manner, when the blood coagulates upon vessels of a green colour.

2101. The coagulation of the blood commences within a few minutes after it has been abstracted from the bloodvessels, and sometimes continues even for several days, as in the inflammatory blood of acute rheumatism, so that the proportion of crassamentum appears very small compared with the amount of serum in which it floated.

2102. This process is differently affected by a variety of circumstances, some of which accelerate it, others again retard it, but the precise conditions under which these modifications are effected are not all determined.

Temperature affects the coagulation in a very marked manner; blood which coagulates in 5 minutes at 60° requires 60 minutes to coagulate completely at, 40°. The blood further coagulates quickly in proportion to the degree of exhaustion of the vital powers, and when the air is rapidly exhausted from the vessel in which it is received, this process is observed to take place with great celerity. The quickness of the process of coagulation is further influenced by the character of the stream of the fluid, for when that is large and full it is rapid, but slow if it be small.

Certain alkaline salts, such as the muriate of soda, muriate of ammonia, or the nitrate of potassa, prevent coagulation taking

place. On the other hand, alum, and the sulphate of zinc, or copper promote this change in fluid blood. Venous blood coagulates more rapidly than arterial, and the smaller the quantity, the sooner is the process completed.

2103. Again, certain states of the animal body, immediately preceding, or causing death, interfere with the process of coagulation, as for instance when death takes place in consequence of a stroke of lightning, or is preceded by some powerful mental emotion, or immediately follows severe and excessive physical fatigue, as in animals hunted to death.

2104. Stir some newly drawn blood with any solid substance, as a bundle of twigs; the fibrine in general adheres to it, and the colouring matter is retained by the serum or fluid portion.

2105. Take some fluid blood from which the fibrine has been separated, in the manner directed in the preceding paragraph, and pour a small portion into flasks or bottles filled with oxygen, hydrogen, nitrogen, and carbonic acid gases; or, a portion of the coagulum of blood may be introduced into these gases. The colour brightens slowly where the blood is exposed to oxygen, or air, which contains oxygen in such a state that it can easily be transferred to the blood. And further, the brightening is not produced unless a certain proportion of serum or other fluid be present, containing common salt or some other saline substance in solution.

2106. Put a thin portion of the coagulum of blood under water, and allow it to remain for a considerable time, till the colouring matter is removed.

2107. Put a portion of the coagulum into water containing no saline matter, and observe the dark tint that is produced.

2108. Put another portion into a solution of common salt, and notice the brilliant tint which the colouring matter now acquires.

2109. Add concentrated sulphuric acid to a portion of blood; a peculiar odour may be perceived, which is said to be characteristic of the animal from which it may have been taken.

2110. Dilute with ten parts of water, the serum of the blood in which the colouring matter has been dissolved, by stirring the blood in the manner described for the separation of the fibrine.

2111. Heat it to 149°, when the colouring matter separates

from the albumen, the latter requiring a temperature of 160°
for coagulation. The colouring matter termed HEMATOSINE is
of a dark colour when prepared in this manner. A solution of
the colouring matter, in a more favourable condition for its se-
paration, may be obtained by stirring the coagulum of blood in
water, after having separated as much serum as possible by drain-
ing it on bibulous paper.

2112. Hematosine is black when pure, and brownish-red
when freely dissolved in water. It consists of carbon, oxygen,
hydrogen, and nitrogen, with a small quantity of iron. It co-
agulates at a lower temperature than albumen. It is rendered
red by exposure to the air, or oxygen ; and, as may be distinctly
seen in venous blood, becomes of a highly brilliant hue, when
any of the neutral alkaline salts are added, as the muriate of
soda or nitrate of potassa. By acids, as the carbonic, or alkalis,
it is rendered black.

2113. Procure some serum free from colouring matter, by
allowing newly drawn blood to remain at rest till the serum
has separated in considerable quantity from the coagulum, de-
canting it afterwards with great care.

2114. Repeat with the serum of the blood, all the experiments
described under albumen.

2115. Expose an ounce or two of the serum of the blood to a
very gentle heat till it is coagulated, cut the coagulum into small
pieces, and put it on a filter ; a watery fluid (usually called THE
SEROSITY) exudes, which may be separated easily by pouring more
water on the coagulum. It contains in solution the greater part of
the salts of the blood. Hydrochloric acid may be easily detected in
it by a solution of the nitrate of silver, which gives a curdy preci-
pitate with this liquid. Soda is indicated by the tint which is com-
municated to the flame of the blowpipe lamp, when the solid
matter that remains after evaporating a drop is exposed to it.

2116. According to M. Le Canu, 1000 parts consists of the
following substances :—

Water,	.	.	.	.	.	.	.	.	.	785.590
Fibrine,	.	.	.	.	.	.	.	.		3.565
Albumen,	.	.	.	.	.	.	.	.		69.415
Colouring Matter,	.	.	.	.	.	.	.		119.626
Crystalline fatty Matter, termed Seroline, (Cholesterine),										4.300
Oily Matter,	.	.	.	.	.	.	.		2.270
Extractive, soluble both in Alcohol and Water,								.		1.920

Albumen combined with Soda,	.	.	.	2.010
Chlorides of Sodium and Potassium, with Phosphates, Sul-				
phates, Carbonates of Potassa and Soda,	.	.	7.304
Carbonates of Lime and Magnesia ; Phosphates of Lime,				
Magnesia, Iron, and Peroxide of Iron,	.	.	1.414
Loss,	.	.	.	.	.	.	.	2.586

2117. If we compare the water with the solids of the serum and crassamentum, the following estimate may perhaps be considered as approximating to the average quantity of these materials in 1000 parts.

Water,	.	.	.	.	.	.	.	.	784
Solid Matter of Crassamentum,		.	.	.	.	129
.... Serum,		.	.	.	.	.	87

2118. In the serum, again, the following are the ingredients in 1000 parts, according to Marcet.

Water,	.	.	.	.	.	.	.	.	900.
Albumen,	.	.	.	.	.	.	.	.	86.8
Muriate of Potassa and Soda,		.	.	.	.	6.6
Merco-extractive Matter,		.	.	.	.	4.
Carbonate of Soda,	.	.	.	.	.	.	1.65
Sulphate of Potassa,		.	.	.	.	.	0.35
Earthy Phosphates,		.	.	.	.	.	0.60

The specific gravity varies in general from 1.0527 to 1.057. That of the serum amounts to nearly 1.030.

2119. RESPIRATION consists in the inspiration and expiration of air, during which the air received into the lungs acts upon the blood, the dark purple venous blood changing to the bright and brilliant red colour which is seen in arterial blood. The air penetrates through the thin membrane of the cells of the lungs, numerous experiments, particularly those of Dr Mitchell and Dr Faust, having shewn that air can pass through membranous matter, and affect chemically the contents within. The extensive surface on which the fluid is spread in the cells of the lungs, must be peculiarly favourable for the absorption of oxygen from the air by the blood, and the evolution of carbonic acid.

2120. Blood agitated with air or oxygen becomes of a florid red in the same manner as in the lungs ; but with nitrogen and with carbonic acid the colour is darkened. The quantity of air affected appears to correspond with the amount of colouring matter in the blood. The presence of saline matter, as in the serum of the blood, is essential to the change of colour ; it *does not take place without it, however freely the air or oxygen*

may be supplied, as Dr Stevens proved. The experiments of Dr Gregory and Mr Irvine have shewn that oxygen is necessary to induce the red tint in the globules diffused through serum, or any similarly diluted solution of saline matter, though the change may be produced in a strong saline solution without any oxygen. SANGUIFICATION is the term applied to the changes that are produced in the fluid derived from the food, as it is converted into blood.

2121. During respiration the quantity of oxygen in the air is diminished, and in man it is replaced by an equal bulk of carbonic acid gas ; in other animals, the quantity of this gas given out is occasionally observed to be greater and sometimes less than the oxygen consumed. Every minute, it has been calculated by Messrs Allen and Pepys, 26 c. i. of carbonic acid are produced ; an estimate considered rather high by many chemists. The air given out from the lungs contains, according to other estimates, 3.6 per cent. of carbonic acid ; according to them, from 6 to 8 per cent. of this gas.

2122. According to Dr Thomson, " there are twenty respirations per minute, and sixteen cubic inches of air taken in and thrown out at each respiration ; we have, therefore, 28,800 respirations in twenty-four hours, and 460,800 cubic inches of air passing through the lungs. $\frac{3.72}{100}$ of this, or 17,141.76 cubic inches are converted into carbonic acid gas. Now, 100 cubic inches of carbonic acid weigh nearly 50 grains ; so that the weight of carbonic acid formed is 8,570.83 grains, $\frac{3}{11}$ths of which, or 2337.5 grains, are carbon."—*Records of Science.*

2123. Dr Thomson's, Dr Prout's, and Dr Fyfe's experiments shew that the quantity of carbonic acid evolved at different temperatures, varies much under different circumstances, and even at different periods of the day.

2124. By a forced expiration, about 200 c. i. of air may, on an average, be expelled from the lungs.

2125. The nitrogen of the air is little affected, apparently, by respiration ; occasionally its quantity appears to be increased, and sometimes it is diminished, the effect varying with the seasons and other circumstances.

2126. Atmospheric air is the only gas that can be respired permanently without injury to life.

Nitrogen and hydrogen may be respired, but do not support

life, in consequence of being incapable of sustaining the chemical changes which oxygen produces upon the blood.

2127. Other gases are extremely deleterious and usually called poisonous gases, as hydrosulphuric acid,* arsenureted hydrogen, cyanogen, phosphureted and carbureted hydrogen. Many others, also, are not only poisonous, but cannot be respired when they approach the glottis in a concentrated form, suddenly inducing a spasmodic contraction, which is apt to produce suffocation ; as chlorine, carbonic acid, binoxide of nitrogen, ammonia, and all acrid acid gases. If, on the other hand, these should be so much diluted as to enter the lungs, the spasmodic contraction not being induced, the most severe and distressing irritation is occasionally experienced for several days, as, when chlorine gas is respired in this manner, the degree of dilution not being great. A case is recorded by Mr Buddle, where strong carbonic acid appears to have entered the lungs, and, though the individual was noticed very soon afterwards, it was found impossible to restore animation.

2128. The skin affects the air much in the same manner as the lungs, carbonic acid being produced and oxygen consumed.

2129. In some animals, respiration is carried on entirely by the skin, and a considerable quantity of carbonic acid evolved.

2130. The most elaborate researches have been made in reference to the phenomena of respiration by Goodwyn, Lavoisier and Spallanzani, Menzies, Davy, Humboldt, Edwards, Dulony, Despretu, and numerous other eminent men of science, a minute account of which may be seen in physiological works, but one point appears hitherto to have been comparatively neglected, viz.—*the amount of air which it may be desirable to supply for sustaining in the most effective manner the functions of life in man*, a question essentially different from that which refers to the amount of air received into the lungs. Under these circumstances, it occurred to me to enter upon this investigation, and having examined the state of the atmosphere in numerous public buildings abroad and at home, as well as in mines, manufactories, on-board ship, and in ordinary habitations, while the construction of five different apartments allowed me to operate on numbers at a time, the largest having on one occasion been

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* See Hydrosulphuric Acid.

crowded with 234 persons at the same moment, I subjoin a condensed view of some of the principal results, the minute details of the experiments being explained in a paper on this subject. It may be proper to add, that two boxes were also provided, capable of being hermetically sealed, or supplied with any quantity of air that might be required, or with any mixture of gases ; one of these was constructed for a single person, and the other for sixteen, and in the experiments in the large apartments, the air introduced was also entirely under control.

2131. The amount of air required for respiration has long been known to be far beyond what passes through the lungs, and in the following statements the term respiration is used in its most extended sense, referring to all that is consumed or required both for the lungs and for the skin, in the function of insensible transpiration.

2132.—1. From two to four cubic feet of air have usually been recommended at ordinary temperatures as a proper supply for the human frame. I have rarely met with any individuals who were satisfied with this amount. Many are not sensible of its evil consequences at the moment, but complain soon afterwards, or rise with headach on the succeeding day. In extremely cold weather, the body being exposed to a very low temperature, a comparatively small quantity is required ; but at ordinary temperatures, I have, in general, allowed ten cubic feet of air per minute, and in warm weather, not oppressively hot however, sixty cubic feet are desirable. In the House of Commons, at one period, this quantity was given, 36.000 cubic feet being supplied every minute for three weeks successively, and a smaller quantity was not agreeable. The functions of the skin and of the lungs appear to demand a supply of air increasing in a far greater ratio than the temperature, which must in part depend on the comparatively smaller cooling power of the air as well as on the state of the respiration, and insensible perspiration.

2133.—2. Different individuals vary as much in the nature of their appetite for air as in their appetite for food and drink. In public buildings more especially, the atmosphere that may be agreeable to some is intolerable to others, a difference to be attributed partly to peculiarity of constitution, and partly to habit.

2134.—3. Three cubic feet per minute for each person is a

supply far above what is often afforded in crowded assemblies, either in public buildings or private dwelling-houses,—a quantity insufficient to maintain the system in that high tone and vigour which it acquires with a larger supply.

2135.—4. A quantity, even considerably less, is more acceptable to most individuals than a larger portion moving in strong currents, or striking unequally upon the body.

2136. Many other circumstances affect respiration independent of the quantity of air supplied.

2137. LIGHT exerts a powerful influence on respiration, and probably on all the functions of life. In experiments where I was subjected to an oppressive atmosphere, I imagined that I always recovered sooner in a pure atmosphere, if I was exposed at the same time to a brilliant light.

2138. The ELECTRICAL CONDITION of the air also affects considerably the state of respiration, but this subject requires a much more extended investigation.

2139. POROUS CLOTHING is extremely important in sustaining the functions of the skin. Languor, disease, and, in extreme cases, even death, may ensue when these are arrested, though the lungs may be supplied with the purest atmosphere.

2140. EXCESSIVE MOISTURE in the air affects not only the heat and electrical conduction of the body, but is an obstacle to the discharge of moisture, both from the lungs and from the skin. In many ill-constructed apartments a restless night may be produced by an unwholesome atmosphere, but be greatly aggravated by superabundant moisture. When the air is too dry, the headach, cough, and harshness of skin which it is apt to induce, ought to be relieved by exposing water in basins to the air of the apartment, sprinkling the floor with it, or introducing steam.

2141. EFFLUVIA from marshes, from the body in a state of disease, and peculiar states of the atmosphere, which have not hitherto been explained, have also great effect upon the system generally. Great difference is observed in different constitutions, some individuals being occasionally overpowered almost instantaneously by particular odours or effluvia, which are comparatively feeble in their action upon others.

2142. In supplying air for respiration generally, it ought to be recollected that the question is not the amount of air with

which a vigorous constitution may be content, but the amount that can be supplied, with a reasonable economy, in the general construction of apartments, and with which the constitution may be supported in the highest tone and vigour. In this country, also, it ought not to be forgotten, that whatever may be the evil consequences of a vitiated atmosphere operating slowly, but insidiously, for a long period upon the system, perhaps as much disease and death has arisen from the inequality with which air is often supplied, especially in many hospitals, where, instead of being admitted so that its impulse is almost imperceptible, it may be traced descending from the window as a waterfall, and perhaps falling continuously, for a considerable time, upon a patient labouring under an inflammatory affection.

2143. In many local situations, it is desirable to purify the air introduced into different buildings, at least, so far as to exclude the minute soot or blacks suspended in it. In London and Manchester, several hundred portions of soot may at times be seen deposited upon a square foot of surface within a few hours.

2144. In examining old wells and pits a candle ought always to be introduced before any one attempts to descend, as the best indication of the presence of carbonic acid, being extinguished at once if the air is so vitiated with carbonic acid as to prove dangerous. It is by no means delicate, however, in its indications, as some constitutions are not much affected when subjected for a limited time to an atmosphere barely containing sufficient carbonic acid to put out a burning candle, while others have had asphyxia induced by a smaller proportion. Again, in some pits, as in some of the large Manchester grave pits in one of the public cemeteries, there is a constant influx of carbonic acid, which appears to collect from the neighbouring strata in the same way that water collects in a well, so that, though it may have been ventilated during the preceding evening, it is unsafe to enter them again next morning till they are again ventilated.*

2145. Again, it must be recollected, that all candles do not burn with equal facility, that an oil-lamp is not so easily extinguished as a candle, and that a gas-lamp burns, though imperfectly, for a long time in an atmosphere that does not support the combustion of either of the former, the light becoming

* See Ventilation.

paler, and at last completely blue, while the flame is greatly extended before it is extinguished.

2146. In various experiments with candles, oil-lamps, and gas-lamps, I have generally found, that in a limited atmosphere containing twenty cubic feet of air, acted upon at the same time by an ordinary-sized tallow-candle and oil-lamp, a fish-tail gas-lamp, and an argand gas-lamp, the observer respiring the same air, the lamps and candles being placed on the floor.

> The candle is extinguished in five minutes.
> ... oil-lamp, *single wick,*   six.
> ... fish-tail gas-burner,   seven to thirteen.
> ... argand-burner,   fifteen.

When the argand was extinguished my respiration was both laborious and hurried, and amounted to about sixty per minute. I could not count my pulse, which was very quick ; and, feeling that I was beginning to be severely oppressed, and losing consciousness, I opened the experimental box. Specimens of air subsequently analyzed, shewed that it contained within a fraction of ten per cent. of carbonic acid gas.

2147. ANIMAL HEAT.—The discovery of carbonic acid in the air disengaged from the lungs during respiration, was made by Dr Black. He considered respiration analogous to combustion, and that the carbonic acid is formed in the lungs. Crawford, adopting his views, believed that the capacity of the blood for caloric is increased at the moment the carbonic acid is produced, and hence the reason why no burning heat is perceived in the lungs ; but the capacity of the blood, he supposed, is diminished as it passes from arterial to venous blood in the extreme capillaries, when the heat that had originally been produced (though not sensible in the lungs) is evolved, diffusing an equal degree of warmth over the whole body. His experiments, however, as to the relative capacities of oxygen, carbonic acid, venous and arterial blood, on which the theory rests, have not been supported by other chemists.

2148. Mr Ellis considered that carbon is separated from the blood as an excreted product, and then acts on the air inspired.

2149. Hassenfratz and Le Grange proposed another view of the manner in which the carbonic acid is produced, and it is most generally received at present. They considered that the oxygen of the air is absorbed by the blood, and a corresponding

quantity of carbonic acid evolved, having been formed in the course of the circulation by the oxygen which had been previously absorbed. Carbonic acid gas has been detected in venous blood, being evolved when it is transferred directly from the living body into an atmosphere of hydrogen gas.

2150. The skin affects the air much in the same manner as the lungs, carbonic acid being produced and oxygen consumed.

2151. In some animals, respiration is carried on entirely by the skin, and a considerable quantity of carbonic acid evolved.

2152. The production of ANIMAL HEAT was considered by Dr Black to depend upon the formation of carbonic acid by the oxygen of the air combining with the carbon of the blood. Numerous experiments have now proved, that the greater the heat produced in the body, the greater the consumption of oxygen in the lungs ; it is also supposed that this operation is not the only source of animal heat, but that it may be developed in part by other operations going on at the same time.

2153. Researches have been made by Brodie and other eminent scientific men, from which it has been concluded that the chemical changes might be induced after death by artificial respiration, without developing a sufficient amount of heat to maintain the body at the ordinary temperature, and that a new source, viz. the nervous influence, must be looked to as the real cause of animal heat. The experiments performed are by no means satisfactory however, nor is there decided proof that all the usual chemical changes were in action, though the blood might have undergone the usual changes of colour in passing from the veins to the arteries through the lungs.

2154. By disease, blood is much altered in its properties. In cases of CHOLERA it is very much affected ; its colour becomes dark, sometimes it acquires the consistence of tar, and is less readily affected by the oxygen of the air. It loses much water, and most of its saline matter, the proportion of albumen and colouring matter being increased. Its density is greater, and it does not coagulate.

2155. Blood occasionally presents a white appearance, owing to the presence of fatty matter in considerable quantity, which is detected by ether dissolving it, and giving a solution, from which it may be procured by evaporation.

2156. In cases of inflammatory action, the crassamentum is covered with a coat of pure fibrine, usually called the BUFFY COAT. This arises from the blood being so altered in its qualities, that the fibrine it contains in solution, coagulates more slowly than the rest of the blood, and part of it is deposited above the red clot. The red globules of the blood are considered heavier than pure fibrine, consisting of a small portion of colourless fibrine in the centre, which is surrounded by the colouring matter of the blood. When the blood is removed from the body, and the colouring matter escapes from the globule, the fibrine from the centre adheres firmly together.

2157. The blood is affected to a great extent in a number of other diseases, though this may not in general be so easily recognised as in the preceding cases, chemical analysis being required to point out the change. Occasionally, however, the change is sufficiently evident, as in jaundice, when the blood acquires a greenish-yellow tint in consequence of the absorption of bile. The BLACK VOMIT observed in yellow fever is regarded as a compound of blood and muriatic acid. Urea is frequently observed in blood, more especially in those cases when the secretion of urine is affected.

2158. Dr Christison has given a table of the relative proportions of hematosine, dry serum, fibrine, and water, in different specimens of blood, more especially in affections of the kidneys; illustrating also the composition of blood from different individuals in full health. The following extract shews the general result :—

	Hemato-sine.	Dry Serum.	Fibrine.	Water.
From a healthy middle-aged and stout seaman, ...	1535	853	52	7562
From a young woman in full health, .	1207	816	25	7952
From a man affected with granular kidney for two months, having been twice largely bled ; the urine was very albuminous, ...	755	572	82	8592
From a young man affected with granular kidney for three months and a half, after scarlatina, . . .	427	973	45	8555
From a man with granular kidney for six months, bled much 18 months before, ...	491	503	56	8870
From a woman seven weeks after copious blood-letting, on account of pneumonia, ...	574	938	44	8441

2159. The following extract from Professor Christison's work on granular disease of the kidney, requires careful perusal by those who may wish to examine the proportions of fibrine, colouring matter, dry serum, and water in the blood. " Dry serum is the term applied to the products obtained on evaporating serum. On some occasions the blood was collected in a bottle containing a few fragments of lead ; and the bottle, after being filled to the lip, was secured with a grooved stopper, and agitated for ten minutes. It was then weighed, to ascertain the quantity of blood made use of. The fibrine which was all collected round the lead, was then separated, well squeezed, slightly washed, squeezed again, and weighed moist. It was next well soaked in repeated portions of water to remove the serum, which may be supposed to constitute its impregnating fluid ; and lastly, dried in the vapour bath till it ceased to lose weight. This gave the amount of dry fibrine. The difference between it and the weight of moist fibrine was carried to the amount of serum. The fibrine being removed, the colouring matter and serum were left at rest for twenty-four hours to separate. The serum was then poured off, weight increased by the supposed serum of the moist fibrine, and its proportion of solid ingredients ascertained by evaporating 200 grains at 212° till they ceased to lose any weight. A simple calculation thus gave the quantity of albumen and salts in the clear serum. The subjacent stratum of mixed serum and colouring matter may be considered as pure hæmatosin, moistened, like the fibrine, with serum, as well as simply mixed with it. The total amount of solid matter being therefore ascertained by evaporating 200 grains, the residuum was held to consist of dry hæmatosin and dry serum. The amount of dry serum was estimated from the loss sustained by evaporation, the whole water being considered to belong to the serum, the solid and aqueous portions of which were known from the previous step of the analysis applied to the clear serum ; and the difference of weight, after subtracting the dry serum from the total weight of the dry mixture, gave the weight of the hæmatosin. This method of estimating the amount of hæmatosin is now generally considered accurate by the best authorities. In thus ascertaining the amount of dry serum and dry hæmatosin after the removal of fibrin, care must be taken to add to the weight of the mixture, the portion of it included

in the fibrin, which, however, is usually very scanty, and which is found by subtracting from the total weight of the blood the 'weight of the mixed serum and hæmatosin PLUS the weight of the moist fibrin slightly washed and squeezed.   It is not always practicable, however, or at least convenient, to collect the blood in the way here explained, although it appears to me the most satisfactory method.   Sometimes we must be content with operating on the blood collected and coagulated in a cup in the usual way.   Here, in the first instance, the cup must be covered to prevent evaporation.   The serum is then poured off from the clot, and both are weighed, and the solids of the serum ascertained as above.   The clot is then inclosed in a small cloth, broken up, gradually squeezed till no more colouring matter drops from it, and the remaining colouring matter on the fingers, in the cloth and in the clot, obtained by washing with water and squeezing again.   The fibrin is then weighed moist, soaked, dried, and weighed as above.   The difference between the total blood, and the moist fibrin and clear serum together, gives the total mixture of serum and hæmatosin, which, by this method, is all saved and collected, but with the addition of a little water, the dry residuum of this mixture is ascertained in the usual way, and its proportional hæmatosin and serum are got at by an obvious calculation."

7. SALIVARY, PANCREATIC, AND GASTRIC JUICES—DIGESTION—BILE.

2160. Little solid matter is found in the SALIVA, scarcely amounting to one per cent.   It consists of a peculiar animal matter and saline substances, with free soda and sulphocyanate of potassa.   Its composition varies much, and it has been observed acid, alkaline, and neutral.

2161. The PANCREATIC JUICE contains a little albumen, curdy matter, osmazome, a free acid (acetic ?), but no sulphocyanic acid.   It was formerly considered similar to the saliva.

· 2162. GASTRIC JUICE.—This fluid is secreted in its proper form only from the stimulus of food, when muriatic acid may often be distinctly traced in it ; to it the great solving powers which it possesses are attributed ; acetic acid is also associated with it.

The muriatic acid is probably derived from common salt and water, and to the soda evolved, as the muriatic acid becomes free, the alkaline reaction of the blood may perhaps be attributed. The stomach itself is supposed to be defended from the action of the corrosive acid by assuming a peculiar electric condition. In cases of sudden death, the stomach is often found corroded in consequence of the action of the acid on its fibres. Gastric juice acts powerfully in coagulating milk.

The gastric juice obtained from the human stomach has the following properties.* It is a clear and transparent fluid, inodorous, with a saline taste, and distinctly acid properties. In taste, it is very like dilute mucilage, slightly acidulated with muriatic acid. In water, wine, or spirits, it is easily diffused, and occasions some effervescence with alkalis. Added to albumen, it is precipitated. It resists the putrefactive process for a considerable length of time, and has the effect of retarding it in other animal matters.

On analysis, it is found to contain muriatic and acetic acids in a free state, along with the phosphates and muriates of potassa, soda, magnesia and lime, and an animal matter, soluble in cold, but not in hot, water.

On mixing the gastric fluid with the saliva, a blue colour is observed, and it becomes frothy. The presence of this acid is only to be recognised when alimentary matter is introduced into the stomach, or when any mechanical irritant, such as stones, are allowed to act on the mucous membrane. It does not appear to be generated during fasting, except in the cases referred to, where local irritations are applied to the stomach. When the stomach is empty, the secreted fluid scarcely displays any acid properties, and hence the incorrect inferences that were drawn, with regard to the nature of the real gastric fluid, from experiments made on the fluid procured from the stomachs of animals fasting.

Recently, it is affirmed that the proper solvent in the gastric juice is not the acid, but that this results from the action of a particular digestive principle, to which the name of PEPSIN has been given by the Germans.

Eberle has ascertained that by digesting mucous membranes

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* *Vide* Beaumont's Observations or Müller's Physiology, p. 517.

in dilute muriatic acid, a substance is obtained analogous in properties to the gastric juice, and consequently capable of exerting the usual solvent effects on the different alimentary matters.

On exposing the mucous membrane derived from the third and fourth stomachs of an ox, to the solvent action of water containing 2.75 per cent of muriatic acid for twenty-four hours, a fluid is procured after filtering, requiring about two per cent. of carbonate of potassa to neutralize it.

This fluid has the property of dissolving the white of an egg (coagulated albumen), at a temperature of $99\frac{1}{2}°$ Fahrenheit, whereas simple diluted acids display no such property.   By the action of the same fluid milk is coagulated, or caseum produced ; and the digestive fluid even seems to possess this power over milk, though its acid is saturated.

2163. The gastric juice acting on the food produces a pulpy mass, termed chyme, from which, in the intestines, a milky fluid, the chyle, is absorbed; this contains the nutritious matter derived from the food, and is conveyed to the heart, and thence to the lungs, where it acts with the air, and is converted into arterial blood.

2164. The insipid fluid formerly described by chemists as gastric juice, must be regarded perhaps as merely a portion of the salivary and pancreatic juices.

2165. Bile is a greenish-yellow coloured fluid, generally rather viscid, having a sweetish bitter taste and nauseous odour. It is heavier than water and alkaline.

2166. Thenard regards the bile of the ox as a compound of about 7 parts of water and 1 of animal and saline matter, composed of—

Picromel.	Muriate of soda.
Resin.	Muriate of potassa.
Yellow matter.	Sulphate of soda.
Soda.	Phosphate of Lime.
Phosphate of soda.	Magnesia and oxide of iron.

The saline matter constitutes a small proportion of the ingredients.

Cholesterine, an odoriferous animal matter, and another peculiar animal matter, osmazome, gluten, cholic acid, and some

fatty substances, have also been found in bile. In human bile, similar ingredients have been detected.

2167. PICROMEL.—Solid, crystalline, soluble in alcohol and water; taste sweet. Prepared from bile by precipitating sulphuric acid and some other substances by acetate of lead, then adding subacetate of lead, the oxide falling with the picromel and resin. By hydrosulphuric acid acting on the precipitate suspended in water, sulphuret of lead is formed, being left undissolved along with the resin; the picromel remains in solution.

2168. CHOLIC ACID is solid, crystalline, reddens litmus, and has a sweet taste.

2169. BILIARY CALCULI are composed principally of cholesterine, and the colouring matter of the bile. Sometimes they contain no cholesterine.

2170. CHOLESTERINE.—White, crystalline, with a pearly lustre. Melts at 278°; does not form a soap with potassa. Insoluble in water; dissolved abundantly by boiling alcohol; sparingly soluble in cold alcohol. By the action of nitric acid, CHOLESTERIC ACID is produced.

8. MILK AND CHYLE.

2171. MILK contains the following substances, of which the first, water, constitutes nearly 929 parts in 1000 :—

Water.	Muriate of potassa.
Butter.	Acetate of potassa.
Caseous matter.	Phosphate of potassa.
Sugar of milk.	Phosphate of lime.
Lactic acid.	Traces of iron.

2172. CREAM contains rather more than 3 per cent. of caseous matter, and 4 of butter, the rest being whey.

2173. WHEY consists principally of water, with small portions of animal matter, and a large quantity of a peculiar saccharine matter, called SUGAR OF MILK, which may be procured by evaporation.

2174. BUTYRINE is the name given to an oily matter which is found in butter.

2175. CASEOUS MATTER is the curdy substance obtained from

milk coagulated by RENNET, the infusion made by the action of water upon a portion of the stomach of the calf, which is powerful in coagulating milk. It always contains in this condition some foreign matter associated with it, being soluble in water when pure, and forming a mucilaginous solution. Sulphuric, nitric, muriatic, and other acids, alcohol, the infusion of galls, and a variety of other substances, coagulate milk by combining with the caseous matter.

2176. Caseous matter is maintained by some chemists to contain two distinct principles, CASEIC ACID, and CASEOUS OXIDE OF APOSÈPIDINE. Others again regard it as approaching very nearly to coagulated albumen in its leading characters.

2177. CHYLE is the milky looking fluid taken up from the chyme. It approaches in its characters to blood, but has only a slight pink tint, and contains less solid matter. It forms a less firm crassamentum during coagulation, and from its serum a flocculent precipitate is obtained by heat, termed by Prout INCIPIENT ALBUMEN. The chyle of two dogs analyzed by him contained from 89 to 94 per cent. of water, the rest being fibrine, incipient albumen, albumen with a slight pink tint, and minute quantities of sugar, and oily and saline matters.

8. OLEAGINOUS AND FATTY SUBSTANCES.

2178. These resemble much in all their leading characters the fixed oils of vegetables. STEARINE, a principle analogous to the margarine of fixed vegetable oils, is found in most of them associated with variable proportions of OLEINE. Berard prepared a substance very similar to fat, by passing through a red hot tube a mixture of carbonic acid, carbureted hydrogen, and hydrogen. Dobereiner succeeded in producing an analogous compound with coal-gas and watery vapour.

2179. STEARINE is obtained with facility in brilliant crystals when deposited from a hot ethereal solution. It is very soluble in hot ether, sparingly soluble in cold ether. It is also soluble in boiling alcohol. Melts at 129°. PREPARED by boiling mutton suet in ether, after melting it to separate any membranous matter, and removing the adhering solution from the crystals by bibulous paper ; this process is repeated with the crystals

several times. Similar processes may be adopted in preparing stearine from other fatty matters.

2180. When boiled with a solution of potassa or soda, it is resolved into STEARIC ACID and glycerine. The stearic acid may be separated by neutralizing the alkali with sulphuric acid.

2181. MARGARINE is the name given to another fatty matter very similar to stearine, but more soluble in ether, and melting at 117. It is procured by allowing the matter separated from the stearine (see 2179) to evaporate and crystallize spontaneously.

2182. Oleine is obtained by pressing lard in bibulous paper, to which it adheres. It is similar to that procured from vegetable substances.

2183. ADIPOCIRE is the term applied to decomposed animal fibre resembling fatty substances.

2184. AMBERGRIS is considered to be a concretion produced in the stomach of the spermaceti whale. It is found floating on the sea coast of India and Africa. It consists principally of a peculiar fatty matter, called Ambreine, which resembles cholesterine.

2185. BUTYRINE is the fatty matter that produces butter.

2186. CHOLESTERINE. See Bile.

2187. DIPPEL's OIL is the name given to a thin limpid oil, the product of the destructive distillation of animal substances.

2188. FAT, HOGSLARD, and SUET, are compounds of stearine and oleine in various proportions ; they melt at various temperatures between 59° and 102°. The stearine and oleine differ often in the fat obtained from different animals.

2189. HIRCINE is procured from the fat of the goat and sheep.

2190. SPERMACETI is prepared from the fatty matter found in the head of the spermaceti whale. Solid, white, crystalline, insoluble in water, soluble in ether and alcohol. Melts at a temperature below 212°. It is usually mixed with a little fluid oil, and is termed CETINE when purified by solution in boiling alcohol and crystallization. ETHAL is a solid fatty matter which remains after the separation of margaric and oleic acids by boiling cetine with potassa or soda, so as to produce soap.

2191. SPERMACETI OIL is the fluid expressed from the fatty matter from which the spermaceti is obtained.

2192. TRAIN OIL is procured by heating blubber to 212°. Its offensive odour arises from decomposed animal matters which are mixed with it.

10. MUCUS, PUS, &c.—LACTIC AND FORMIC ACIDS.

2193. MUCUS.—The existence of a distinct prnciple to which this name has been applied is doubtful. The mucus described by Dr Bostock is soluble in hot and cold water, and does not gelatinize. Tannin and bichloride of mercury do not precipitate it. The mucus of the nose is rendered transparent by water, but not dissolved. It is dissolved by nitric acid, dilute sulphuric acid, and potassa.

2194. PUS varies much in its qualities, according to the nature of the source from which it is produced. Healthy pus is a bland, thick fluid, apparently homogeneous, but composed of a thin transparent fluid, with opaque globules floating in it. Sp. gr. 1.030. Neutral, but becomes acid by the action of the air. Soluble in sulphuric, nitric, and muriatic acids, and in alkalis. Ammonia produces a gelatinous mass with it.

The following are the principal tests which have been proposed for distinguishing pus from mucus :—

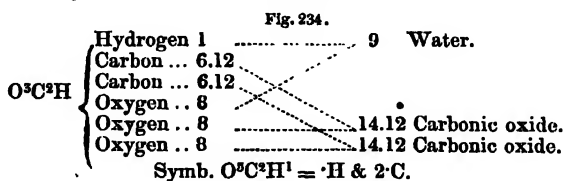| TESTS.	MUCUS.	PUS.
Mixed with an equal weight of water, and then with an equal weight of a saturated solution of carbonate of potass,	does not gelatinize,	produces a jelly.
Diffused through water,	from a catarrh, it floats.	precipitated.
Dissolved in potassa, and water added,	not affected.	precipitated.
Dissolved in sulphuric acid, and water added.	remains suspended in the water.	precipitated.

2195. FLUID OF SEROUS SURFACES.—Composed principally of water, with small portions of albumen, mucus, and saline matter. The LYMPH which lubricates the cellular membrane is considered of analogous composition. Small portions of LACTIC ACID are also found in it.

11. Lactic and Formic Acids.

These acids being more frequently referred to than any other acids derived from the animal kingdom, except the uric acid, a short notice of them is given in this place.

2196. Lactic Acid has been found in most animal fluids, and in a number of vegetables. It was first obtained from sour milk, from which its name is derived. Its concentrated solution is syrupy, very acid, and can displace acetic acid from its combinations. It is prepared by evaporating solutions containing it to a syrupy consistence, extracting the lactic acid by alcohol. By combination with oxide of zinc, separating it afterwards by baryta, and ultimately removing the baryta by sulphuric acid, it is obtained in a pure form.

2197. Formic Acid. *Symb.* O^3C^2H=oxygen 24+carbon 12.24 +hydrogen 1. *Eq.* 37.24. The name given to the acid obtained from the acid liquid of ants. It may be formed artificially by distillation from tartaric acid mixed with diluted sulphuric acid and binoxide of manganese. It will be seen from the annexed diagram that it may be regarded as a compound of 2 eqs. of carbonic oxide and 1 of water, into which it is easily resolved by heating it cautiously with strong sulphuric acid.

Fig. 234.

Hydrogen 1 .... 9 Water.
Carbon ... 6.12
O^3C^2H { Carbon ... 6.12
Oxygen .. 8
Oxygen .. 8 ....14.12 Carbonic oxide.
Oxygen .. 8 ....14.12 Carbonic oxide.
Symb. $O^3C^2H^1 = \cdot H$ & $2 \cdot C$.

Urine, Urea, Uric, Purpuric, and Cyanuric Acids.

2198. Urine is a pale amber-coloured liquid. Sp. gr. 1.0224. It is generally acidulous at first, and soon becomes alkaline. The following is Berzelius's analysis of urine. Sp. gr. 1.0224.

Water, ...	933.00
Urea, ...	30.10
Uric acid, ...	1.00

Free lactic acid, and lactate of ammonia, with animal matter,						17.14
Mucus of the bladder,	.	.	.	.	.	0.32
Sulphate of potassa,		.	.	.	.	3.71
... soda,		.	.	.	.	3.16
Phosphate of soda,	.	.	.	.	.	2.94
... ammonia,		.	.	.	.	1.65
Muriate of Soda,	.	.	.	.	.	4.45
... Ammonia,		.	.	.	.	1.50
Earthy matters, with a trace of fluate of lime,			.		.	1.0
Siliceous earth,	.	.	.	.	.	0.03

Sulphur, phosphorus, and albumen, have also been detected in minute proportions. Benzoic acid is found in the urine of young persons, and of graminivorous animals.

In numerous cases of disease the urine is frequently very much altered.

2199. UREA. *Symb.* 2 (H^2OCN) = hydrogen 4 + oxygen 16 + carbon 12.24 + nitrogen 28.4. *Eq.* 60.64. Solid; crystallizes in four-sided prisms; sp. gr. 1.35; very soluble in water and alcohol; not acid nor alkaline. Decomposed quickly by heat, producing carbonate of ammonia and cyanuric acid. Decomposed quickly as it exists in urine; but its solution in water, when pure, is not speedily decomposed.

2200. With nitric acid it forms a sparingly soluble crystalline compound. This acid is accordingly employed to detect urea.

2201. Preparation. Evaporate urine to the consistence of a syrup. When cold, add gradually nitric acid (free from nitrous) till a dark crystallized mass is formed, composed principally of nitric acid and urea. Wash it repeatedly with cold water, and dry by pressure between folds of bibulous paper. Dissolve carbonate of potassa in three parts of water; add the solution till the nitric acid is neutralized; evaporate the solution, that the nitrate of potassa may crystallize on cooling. · Mix the drainings from the crystals, which contain urea in solution, with animal charcoal, so as to produce a thick paste. After six or eight hours add cold water to extract the urea, thus freed from colouring matter. Filter, and evaporate the solution to dryness. Boil the urea in alcohol, then filter, and crystallize.

2202. Urea is formed also when water is heated with cyanate of ammonia, one eq. of water with one of cyanate of ammonia containing the same elements in the same proportion. The

diagram shews the relation that urea and the aqueous cyanate of ammonia bear to each other.

Fig. 235.

Symb. $2 H^2 CNO = \cdot H + \cdot C^2 N + NH^3$.
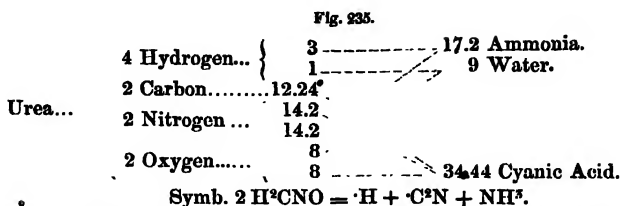
The aqueous cyanate of ammonia is supposed to be in solution.

2203. By examining the ·changes symbolically, and with the aid of a diagram, the production of carbonate of ammonia by the action of water with urea may be easily seen. The two eqs. of carbonate are supposed to be in solution.

Symb. $2 \cdot H$ & $2 H^2 CNO = 2 (\cdot C + NH^3)$.
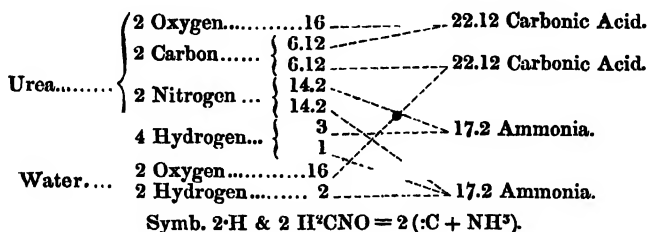
2204. The symbol of URIC or LITHIC ACID is $O^3 C^6 H^2 N^2 =$ O.24 + C.36·72 + H.2 + N.28·4. Eq. 91.12. It is white when pure, but generally of a brownish colour, tasteless, inodorous, insoluble in alcohol. 10,000 parts of cold water are required for its solution. It reddens litmus feebly, is expelled from its salts by carbonic acid, but, if boiled with carbonates, it expels carbonic acid.

2205. PURPURIC ACID is particularly distinguished by the brilliant-coloured purple compounds which it forms with several of the salifiable bases. It is formed in combination with ammonia by the action of nitric and uric acids.

2206. CYANURIC ACID, called also Pyrouric Acid, is formed when uric acid is heated, or by the action of chlorine on different compounds containing cyanogen and water. Urea also may be made to produce this acid. *Symb.* $O^2 C^2 HN$.

2207. The decomposition of uric by nitric acid, is a much more complicated subject than was previously suspected. The following is a very general summary of the new compounds discovered by Wohler and Liebig, whose elaborate paper on the uric acid may be seen in a very recent number of the Annales de Chimie et de Physique.

Uric acid is decomposed by diluted nitric acid, producing carbonic acid and nitrogen, and leaving nitrate of ammonia, along with alloxantine, urea, and free nitric acid.

By heating the solution, the alloxantine is changed into alloxane, taking oxygen from the nitric acid.

One part of the alloxane is resolved, by the nitric acid, into oxalic and parabanic acid.

Another part is changed into oxaluric acid, and part of this is resolved into urea and oxalic acid.

By neutralizing the solution with ammonia, a great variety of changes may be observed, the precise nature of which is much influenced by relative quantities of alloxantine and alloxane which the solution may previously have contained.

2208. ALLANTOINE is similar to the allantoic acid, and is produced, according to Wohler and Liebig, when uric acid is boiled with binoxide of lead, urea, oxalic acid, and carbonic acid being formed at the same time. It is termed Allantoine instead of Allantoic Acid, as it is not now considered to possess the properties of an acid.

OXALURIC ACID is considered as a compound of the same elements as oxalic acid, and urea.

ALLOXANE may be regarded as a compound of allantoine and oxalic acid.

ALLOXANTINE is one of the products formed by the action of nitric acid on uric acid, or by the action of sulphureted-hydrogen on alloxane.

THIONURIC ACID is formed by the action of sulphurous acid with ammonia and alloxane.

URAMILE is produced on boiling thionuric acid, or the thionurate of ammonia, with sulphuric and muriatic acids.

DIALURIC ACID has been produced from alloxane, by depriving the latter of a portion of oxygen.

PARABANIC ACID is formed when nitric acid is moderately concentrated, and is heated with uric acid.

ALLOXANIC ACID is formed when alloxane is brought in contact with different salifiable bases.

MUREXIDE is the term applied to the purpurate of ammonia of Prout, and is produced by the action of ammonia on alloxane and alloxantine formed by nitric acid acting on uric acid.

MUREXANE is obtained by dissolving murexide in a solution of caustic potassa, and precipitating by the addition of diluted sulphuric acid.

The Mesoxalic, Mycomelic, and Uramilic acids, are the terms applied to three other acids, also discovered by Wohler and Liebig.

2209. The urine is subject to an extreme variety of changes in consequence of disease. Sometimes the watery portion, and on other occasions the solids, abound ; and very frequently some ingredient is accumulated in excess, or a vitiated secretion induced, containing ingredients which are not found in healthy urine. Hence its appearance, odour, and specific gravity, are subject to great changes, which are often much increased by the presence of blood, pus, sediments, mucus, albumen, and other animal matters, mingled occasionally with fragments of calculi. Several instances have also been recorded in which the urine was noticed to be luminous when voided in the dark, a property attributed to the presence of free phosphorus.

2210. SUGAR is found in considerable quantity in the urine of individuals affected with diabetes ; 6 per cent. of sugar may often be procured from it. Professor Kane obtained a still larger quantity.

2211. ALBUMEN is often found in large quantity in the urine of individuals affected with some varieties of dropsy, coagulating when exposed to heat, or by the action of acids, like the serum of the blood. In some cases it has coagulated even within the bladder.

2212. UREA is sometimes found in excess in urine. Dr Prout states, that, when this is the case, nitric acid added in an equal bulk to a few drops of urine in a watch-glass, produces a crystalline precipitate of nitrated urea in half an hour. Healthy urine produces it more slowly. It is not absent in diabetic urine, as was at one time supposed.

2213. In some diseases of the liver, the urine becomes tinged

with bile, and has a deeper yellowish tint than usual. Muriatic acid produces a green tint in urine charged with bile.

2214. In calculous affections the urine deposits various concretions of a stony looking matter, the more important of which are referred to in the succeeding paragraph.

Experiments Illustrating the Method of Examining the most important varieties of Calculi.

2215. Cut one or two biliary calculi into small pieces, triturate them in a mortar, and boil them for ten minutes in a test tube or small flask, with twenty times their bulk of alcohol. On filtering the solution, a clear and colourless liquid is usually obtained, which deposits pearly looking crystals of CHOLESTERINE as it cools. If the solution be very strong, a layer of cholesterine will be left upon the paper by the alcohol as it passes through, and on drying the filter and bending it backwards, it may be detached in the solid form, still retaining the figure of the filter on which it had collected, and having the appearance of a fine membrane with a pearly lustre. Some biliary calculi contain little or no cholesterine, but in general they consist entirely or principally of this substance.

2216. In preparing cholesterine from biliary calculi, it is necessary to filter the solution as speedily as possible, as this substance is very sparingly soluble in cold alcohol, and a great portion of it is deposited on the filter in operating with small quantities, if this precaution be not attended to.

2217. Reduce a portion of a URIC ACID calculus to powder, and digest it in a diluted solution of potassa. Urate of potassa is soon formed and remains in solution, while any earthy phosphates that may have been mixed with it remain undissolved.

2218. Filter the solution of urate of potassa prepared in the manner described in the preceding paragraph, and add an acid to it as long as any precipitation takes place. The acid combines with the potassa, and uric acid is precipitated.

2219. Mix some uric and nitric acids, and expose the mixture to a gentle heat till it becomes dry, taking care not to allow the temperature to become so high as to decompose the products;

a solid mass is obtained of a deep red colour. When a very small quantity of materials is employed, so as to leave only a very thin pellicle on the surface of the glass on which it is heated, it has a bright pink colour.

2220. Expose a small piece of an uric acid calculus to heat in a platinum spoon held in the flame of a spirit-lamp; it soon blackens and emits a fetid odour, and in a short time it entirely disappears, when composed of nothing but uric acid; in general, however, an ash-coloured matter remains, composed of some of the saline substances, that form the basis of a number of other calculi, and occur in variable proportions in the uric acid calculus.

2221. The URATE OF AMMONIA calculus is comparatively rare; and till lately the formation of calculi of this kind was disputed. It may be easily distinguished from the uric acid calculus, however, when not mixed with a large quantity of uric acid, by its greater solubility in water, its clay colour, the ammoniacal odour which is exhaled when it is gently heated with a strong solution of potassa, and its solubility in solutions of the carbonates of potassa and soda, which do not dissolve pure uric acid.

2222. The OXALATE OF LIME, or mulberry calculus, is in general easily known by its rough tuberculated surface, and its chemical composition may be easily proved by a few simple experiments.

2223. Expose a portion of this calculus to heat over a spirit-lamp, holding it in the flame till nothing remains but a grey-coloured ash; it becomes black at first, and the residue will be found to be composed of carbonate of lime, dissolving with effervescence in hydrochloric acid, and forming a solution of hydrochlorate of lime, with which the experiments described in 887, page 258, may be performed, after neutralizing any excess of acid by an alkali.

2224. Place another portion of this calculus on a piece of charcoal, and expose it to a strong heat before the flame of the blowpipe; nothing will remain but caustic lime, which slakes in the usual manner, renders turmeric paper brown, and paper tinged with the blue infusion of cabbage green, on rubbing it on them with a little water.

2225. Reduce a portion of the PHOSPHATE OF LIME or *Bone*

Earth calculus to powder, and digest it in diluted nitric or hydrochloric acid. In a short time it is completely dissolved, and if the acid be neutralized by an alkali, it is again .precipitated. It is not soluble in cold acetic acid.

2226. Expose another portion of this calculus to heat before the flame of the blowpipe; it soon, becomes black from the decomposition of a little animal matter with which it is always mixed, and the separation of part of the carbon; this is soon burned off, however, and nothing remains but the phosphate of lime of a pure white colour, which does not suffer farther change by any ordinary heat to which it may be exposed.

2227. Digest another portion of this calculus in a solution of potassa after reducing it to powder; if it consist solely of phosphate of lime, no reaction takes place, phosphate of lime being insoluble in a solution of potassa; but if any uric acid should have been mixed with it, urate of potassa is found in the solution, from which the uric acid may be precipitated by an acid.

2228. Uric acid may be detected also in calculi composed principally of phosphate of lime, by evaporating its solution in nitric acid to dryness in the manner described in 2219, when the characteristic red tint appears, though only a very minute quantity of this substance should have been present in the calculus. There are few urinary calculi which do not give traces of uric acid when treated in this manner, whatever may be the ingredient of which they are principally composed.

2229. If the phosphate of lime calculus be treated with aqueous sulphuric acid in* the manner described under phosphorus and its compounds, phosphorus or phosphoric acid may be procured from it.

2230. When the calculus is supposed to consist of PHOSPHATE OF AMMONIA and MAGNESIA, this may be easily ascertained by heating a portion in a solution of caustic potassa after reducing it to powder, when ammonia is disengaged, the phosphoric acid in combination with it uniting with the potassa; and by treating another portion with cold acetic acid, the phosphate of ammonia and magnesia is dissolved, leaving the greater portion of any phosphate of lime that may have been mixed with it.

2231. When the calculus is composed of a mixture of phos-

phate of ammonia and magnesia and phosphate of lime, it fuses readily before the blowpipe, and hence it is usually termed the FUSIBLE CALCULUS.

2232. Mr Venables has lately confirmed the existence of another variety of urinary calculi not hitherto noticed in this country; the specimens he procured were in the form of a SILICEOUS GRAVEL. The presence of silica was clearly proved by the chemical examination, being insoluble in nitric or hydrochloric acid, not affected by the heat of the blowpipe when freed from adhering saline matter, but undergoing a semifusion along with them into a scoriaceous mass, and fusing readily with the fixed alkalis into a vitreous globule; if three times its weight of carbonate of potassa be employed, the globule, when boiled with water, gives a solution of silicated potassa, from which the silica is precipitated by a solution of muriate of ammonia. With some of the grains it is easy to scratch glass.—*Quarterly Journal of Science* for 1829, vol. vi.

The CYSTIC OXIDE and XANTHIC OXIDE calculi are so rare, that few students can expect to have an opportunity of operating with them.

2233. The CYSTIC OXIDE calculus is easily distinguished from all the preceding varieties of calculi by its solubility in solutions of acids, alkalis, alkaline carbonates, and in lime water; it is also completely decomposed by heat, being composed of the usual elements of animal matter.

2234. The XANTHIC OXIDE calculus is distinguished by the lemon yellow coloured residue that is left on exposing its solution in nitric acid to heat.

The FIBRINOUS CALCULUS is still more rare than either of the preceding, and is composed entirely of fibrine.

2235. CARBONATE OF LIME has also been found, though rarely, in urinary calculi; in some cases nearly pure, and occasionally mixed with other substances.

PART II.

GENERAL PRINCIPLES OF CHEMISTRY.

2236. The term MATTER is applied to every thing that occupies space, and is attracted by the earth. All such substances have weight ; and, when the quantity is small, it can be retained or confined in vessels for an indefinite period. But one or more kinds of matter, of a much more subtle and penetrating nature, are also believed to exist, though, of this, no direct proof has hitherto been given, it being considered that the phenomena of light, heat, electricity, and magnetism, are explained most satisfactorily on this hypothesis. Such matter, if it do exist, has no appreciable weight, neither can it be retained or confined for any length of time in vessels. It is the former alone that is understood at present, viz., matter of a more palpable nature, such as can be easily recognised by the senses, or, at least, made manifest by instruments, should it be thin and invisible like the air.

2237. Matter is presented to our notice in four very different conditions at the surface of the globe, viz., in the solid, liquid, gaseous, and vesicular form. *Air* is a specimen of matter in the thin and attenuated condition in which it is called a gas or vapour ; and, in *clouds*, we have a good illustration of matter in the form of vesicular vapour. The condition of matter is accidental, and dependent on the relation of each individual substance to heat, and, in the vesicular form, probably also to electricity. Thus, water is familiar in the solid, liquid, gaseous (steam), and vesicular form.

2238. No matter with which man is acquainted is devoid of heat and electricity, neither is it known what form or bulk, or change in its condition, might ensue, were it deprived entirely of either, or of both.

2239. Matter is known only by its properties. These are divided into primary and secondary properties. The PRIMARY PROPERTIES of matter may be observed in all bodies, viz., EXTENSION, IMPENETRABILITY, and INDESTRUCTIBILITY. Matter is essentially extended, or occupies space. One portion does not allow another to occupy the same space it does at the same moment; there may be displacement, but there is no actual penetration. Nor is any portion ever destroyed, though a change of arrangement and appearance may take place. Matter is also said to have INERTIA, and to be equally incapable of spontaneously originating motion, or arresting itself when in motion.

2240. The SECONDARY PROPERTIES of matter are GENERAL or PARTICULAR. The former may be observed in all kinds of matter, as the power of attraction or repulsion; but the latter vary indefinitely in each particular substance, forming the special characters by which one kind of matter is distinguished from another, as in form, colour, texture, hardness, &c.

2241. All matter, apparently inert or quiescent, is retained in its present position by powers of attraction, which bind it more or less to the materials upon which it rests. All matter in motion has this motion regulated by various attractive forces operating upon it; but, in particular circumstances, a repulsive movement is determined, and matter separates from matter. All changes induced in matter arise from the operation of powers of ATTRACTION and REPULSION, acting either separately or conjointly.

2242. Attraction operating between masses of matter is termed GRAVITATION. Exerted between particles of the same kind of matter, in the nearest possible contact, it is called COHESION, or the ATTRACTION of AGGREGATION; and when it operates between particles of different kinds of matter, also as near as possible, it is denominated CHEMICAL ATTRACTION or AFFINITY.[*]

2243. The WEIGHT of bodies depends upon their being attracted to the earth. The DENSITY or SPECIFIC WEIGHT of any body is the peculiar density or weight it may have when that is contrasted with the weight of an equal bulk of some well known substance taken as a standard of comparison.

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[*] This term was introduced, on the supposition formerly maintained, that those bodies only attracted each other chemically which had some resemblance to each other.

2244. All masses of matter are composed of particles or atoms so small, that millions of them are contained in a single grain. How far any mass must be subdivided before we arrive at these primitive particles, has not been ascertained.   They possess all the essential properties of matter, and are not mere mathematical points, as was at one time maintained.   None has ever been seen by itself, in consequence of their extreme minuteness ; and they are considered indivisible, not from any direct demonstration that this is actually the case, but from numerous facts, more especially those that relate to the proportions in which bodies combine.   It will be seen, then, that it is essential to distinguish between mathematical divisibility, which these atoms may have in common with all other matter, and physical indivisibility, or the power of resisting any attempt that may be made to break them into smaller parts, a property which belongs exclusively to them, and is not met with in masses of matter, however great the cohesion may be.

2245. Divisibility, accordingly, is not correctly designated a property of matter, but rather a property of masses of matter.

2246. Porosity, also, is more properly termed a property of masses of matter, the pores existing between the particles of which they are composed.

2247. Compressibility, in the same manner, refers to masses of matter.   Gases are much more compressible than solids or liquids.   Elasticity is the power a body has in recovering its former shape, bulk, or position, when the compressing power is removed.   Elastic solids, subjected to great compression, are often so altered in their texture, as not to recover entirely their original shape and form when the compressing cause is removed. But this is not the case with liquids and gases.

2248. Polarity indicates a disposition in the particles of matter to move, or be attracted, or cohere to others by certain parts or poles, instead of forming a confused mass ; and hence the regularity and order which is every where observed when the particles of matter have free liberty of motion, and are not prevented by any rude mechanical force from obeying those movements which their polarity induces, when placed in circumstances favourable for its action.

I. Chemical Action.

2249. Matter, considered chemically, is either SIMPLE or COMPOUND. Iron is termed a simple substance or an ELEMENT, because, do what we may with it, nothing can be extracted from it but iron. But iron-pyrites is a compound, as, however homogeneous it may appear, it can be resolved into iron and sulphur.

2250. Compounds contain two or more elements; and, when several compounds are separated from a more complicated combination, they are usually termed PROXIMATE PRINCIPLES. ULTIMATE PRINCIPLES are the elements of which proximate principles are composed.

2251. An INTEGRANT PARTICLE is the smallest portion, viz., an atom of any element or compound. The elementary particles in compound atoms are often termed COMPONENT or CONSTITUENT PARTICLES.

2252. All chemical action consists in the more intimate union of particles of matter previously brought into the nearest possible contact by mixture, or in the separation of those that may have previously been attached to each other. COMBINATION or SYNTHESIS are the terms employed to denote the union of different kinds of particles, and DECOMPOSITION or ANALYSIS to express their separation.

2253. No chemical action can ensue where the materials are not brought into the nearest possible contact.

2254. All bodies are believed to attract each other chemically, but not with equal force ; and the particles of some kinds of matter appear to have more attraction for each other than for the particles of other kinds of matter.

2255. Neither does chemical attraction operate with the same force at all times between the same substances, being modified by the circumstances under which they may be presented to each other, especially by the action of heat, light, and electricity. Again, chemical action is much influenced in some cases by peculiar powers, forces, or arrangements, whose mode of action is by no means well understood, and where the introduction of a third substance promotes or induces great changes which would not otherwise take place, though it does not appear to be sensibly affected ; as, when hydrogen gas is directed upon spongy

platinum, air or oxygen being also present, the hydrogen acts on oxygen and is inflamed, although the platinum is in no way affected. Many powders which are very porous, and can condense gases, present this property in a remarkable degree.

2256. Were chemical attraction to operate equally between all substances, all the elements of which the globe is composed would rush into a mass, where no variety of form would adorn the face of Nature. The distinctions of the animal, vegetable, and mineral kingdoms, would disappear from the face of the earth.

2257. In chemical action, great variety may be observed in the constitution of the product formed, according to the nature of the particles coming into play, as in the following illustrations.

1. One element may combine with another. Sulphur and iron form sulphuret of iron.

2. Two or more compounds may enter into combination. Sulphuric acid and oxide of iron form sulphate of iron.

3. An element and a compound may combine. Iodine combines with water.

4. A compound may be resolved into two elements. Red oxide of mercury is resolved by heat into oxygen and mercury.

5. Two compounds may be separated. In decomposing limestone by heat (burning it according to the popular term) carbonic acid, a compound of carbon and oxygen, leaves lime, a compound of calcium and oxygen.

6. An element may be liberated from other materials which may remain in combination. As when oxygen is separated from chlorate of potassa, chlorine and potassium are left in combination.

2258. Chemical action is often complicated in a greater degree by the production of one compound frequently accompanying the decomposition of another; and also by successive combinations and decomposition dependent on those which may have ensued at first. Hence chemical action is said to be direct or secondary. It is DIRECT or PRIMARY, when it takes place between materials which act upon each other in the condition in which they are mingled. It is called INDIRECT or SECONDARY when it arises from the products of a first reaction producing a second, or from one of the products of the first action inducing another by its action on part of the materials in the condition in which they were originally employed.

CHAPTER I.—PHENOMENA OF CHEMICAL ACTION.

2259. The particles or atoms between which chemical action ensues being so exceedingly minute, that they are invisible to man, even when assisted with the most powerful instruments hitherto constructed, it is only from the phenomena of chemical action and the change of properties that ensues, that we are as sured of those changes which may actually have taken place.

2260. Change of properties in the substances affected is the most characteristic sign of·chemical action. This is often accompanied by more transient phenomena, as the evolution of heat, and light, and electrical changes. When the characteristic properties of the combining bodies are lost in the new compound, it is called NEUTRAL, and the component parts are said to have NEUTRALIZED or SATURATED each other. A body is also said to be saturated with another, when it does not enter into combination with any more. Changes in the form (in the solid, liquid, or gaseous forms), colour, density, power of attraction for other bodies, and in relation to light, heat, electricity, and magnetism, are continually presenting themselves in chemical action.

2261. When substances possessing any property in common combine chemically, the compound formed frequently presents this property also, and often in a more eminent degree than either separately. Thus, metals in combining do not lose their metallic form. Hydrogen and phosphorus, both of which are inflammable, produce a compound which is inflamed so easily that it burns spontaneously at natural temperatures, when it comes in contact with the air.

2262. A solid thrown down from a gas or from a liquid is said to be PRECIPITATED. EFFERVESCENCE is the rapid evolution of a gas from a liquid. SOLUTION refers to the union of any substance with a liquid or gas, disappearing in them in the same manner as when sugar is dissolved in water.
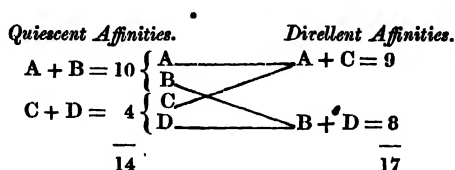
CHAPTER II.—FORCE OF AFFINITY.

2263. The force with which the particles of different substances act upon each other is extremely great, being sufficient to disintegrate the most cohesive solids, and separate their particles individually from each other. Hitherto, however, no method of ascertaining the precise amount of force exerted has been pointed out; neither is a superiority of affinity exerted by any substance to another, in any particular case, an indication that it will possess this superiority equally in all other cases. Thus, if the relative strength of attraction of lime for carbonic acid, and of potassa for carbonic acid, be estimated by their mutual action at ordinary temperatures, lime is superior to potassa, as it then removes the carbonic acid from potassa. But if lime and potassa be both combined with carbonic acid and exposed separately to a red heat, then the lime appears inferior in its power of action with carbonic acid, losing it entirely at that temperature, while it is retained by the potassa.

2264. When any substance leaves another with which it may have been combined, and attaches itself to a third, this is termed in the language of Bergman, a case of SINGLE ELECTIVE AFFINITY. But when two compounds mutually decompose each other, an exchange of principles taking place, and two new compounds being at the same time produced, this is termed a case of DOUBLE ELECTIVE AFFINITY, or of DOUBLE DECOMPOSITION.

2265. The affinities tending to retain matters in their previous state of combination are termed QUIESCENT AFFINITIES. Those, again, that tend to produce new compounds are named DIVELLENT AFFINITIES.

2266. By bringing different affinities into operation at the same moment, combinations and decompositions may be effected which cannot be produced by any of them alone. Thus, if A attract B with a force equal to 10, C, also attracting A, cannot withdraw it from B, operating only with a force of 9. Neither can D separate B (for which it has an affinity of 8) from A, A and B being united with a force equal to 10. But

if the compound C D, whose elements, A D, are united with a force equal to 4, be brought in action upon A B, a decomposition immediately ensues, the divellent overpowering the quiescent affinities, and the two new compounds A + C and B + D are formed.

$$
\begin{array}{ll}
\textit{Quiescent Affinities.} & \textit{Divellent Affinities.} \\
A + B = 10 \begin{cases} A \\ B \end{cases} & A + C = 9 \\
C + D = 4 \begin{cases} C \\ D \end{cases} & B + D = 8 \\
\overline{14} & \overline{17}
\end{array}
$$

CHAPTER III.—CAUSES WHICH MODIFY AFFINITY.

2267. Affinity was considered by Bergman as an invariable force. Berthollet had the merit of pointing out that it is modified by a great variety of circumstances, the more important of which are the following, excluding at present, the consideration of the influence of light, heat, and electricity, which will be attended to under these respective subjects.

Sect. I.—Quantity of Matter.

2268. The chemical action of bodies is necessarily in the ratio of the strength of affinity exerted, and the quantity brought into action. But the increase to an indefinite extent of the quantity of any substance added to a limited portion of another, does not necessarily increase its chemical agency ; for, when it exceeds a certain portion, any excess may be beyond the sphere of chemical action, and never come into play upon the smaller portion of matter to be affected.

2269. The admixture of various proportions of the same ingredients often determines the production of very different primary or secondary combinations.

2270. The larger the amount of any substance combined with another, the more easily is a portion removed. The smaller the amount of any body combined with another, the greater the fa-

cility with which an additional quantity may be made to enter into combination.

SECT. II.—COHESION, STATE OF COMBINATION, ELASTICITY, INSOLUBILITY, SPECIFIC GRAVITY.

2271. By COHESION the particles of masses are retained together. It is, therefore, an obstacle to combination, and hence, by grinding, rasping and pulverizing, solution and all other operations which tend to overcome cohesion, chemical action is often greatly facilitated.

2272. STATE OF COMBINATION. This has a most important influence on chemical action. Bodies vary much in their disposition to affect others according to the condition they may have acquired. Occasionally they acquired the power of combining with bodies for which they had no attraction. In other cases, they lose the property of affecting particular substances which they may previously have possessed.

2273. ELASTICITY. The elasticity of bodies affects much their tendency to combination, compounds being frequently formed when this is increased or reduced which cannot be formed under other circumstances.

2274. An elastic or gaseous substance evolved in any operation being generally removed as it is disengaged, does not tend to produce any secondary reaction by accumulating as the decomposition advances in consequence of which it is eliminated.

2275. The history of chemical action under increased and diminished pressure, has hitherto received comparatively little attention. But since the important experiments performed by Sir James Hall upon the fusion of marble under pressure, and the artificial formation of coal, it has always been a subject of great interest. The more recent experiments of Faraday on the condensation of the gases, along with the proposal for employing condensed carbonic acid as a moving power, have directed an increasing attention to the investigations connected with the influence of elasticity upon chemical action.

2276. The SPECIFIC GRAVITY of bodies, by affecting their mobility, influences chemical action. Thus a solid at the bottom of a liquid affecting it, in many cases, soon becomes covered

with a saturated solution, whose density may prevent farther changes. But if the same solid be suspended in the upper portion of the liquid, the dense solution formed around it continually subsiding, a fresh surface is constantly exposed to a fresh portion of fluid, and a more complete and rapid action ensues. The specific gravity of the materials used in chemical operations requires constant attention in order to bring them to a successful result.

2277. INSOLUBILITY. An insoluble compound formed around a solid subjected to the action of any chemical agent, often arrests entirely the progress of the decomposition. If it be removed mechanically, the chemical action is renewed. Again, insoluble substances separated 'from any solution are removed comparatively from the sphere of action, and not so apt to exert a secondary action upon any of the new compounds.

CHAP. IV.—PROPORTIONS IN WHICH BODIES COMBINE.

SECT. I.—DOCTRINE OF DEFINITE PROPORTIONS OR CHEMICAL EQUIVALENTS.

2278. SINCE the existence of chemistry as a science, no principle has been pointed out so broadly connected with the whole range of its investigations, as the law of combination in definite proportions. It embodies not only some of the most brilliant discoveries, but also many of the most useful practical applications of the science,. and has enabled the accumulated mass of facts which it now embraces to be reduced to a comparatively systematic form.

2279. It is not, therefore, surprising that it should have effected a very important change in the character of the science, and been so assiduously cultivated by the chemists of the present day. Little more, indeed, than thirty years have elapsed since Mr Dalton made known his views of chemical combination, and though they were blended with certain speculations regarding the atoms or ultimate particles of matter, which have

not in all their extent been so generally admitted, they now form the basis of the principles of chemical science.

2280. Dr Thomson was the first who explained publicly Mr Dalton's views of chemical combination, and Dr Wollaston's and Dr Thomson's experiments on the composition of some salts of oxalic acid and potassa led chemists to examine them with attention. Dr Wollaston founded on them his scale of chemical equivalents, and it is to it, in a great measure, as Dr Thomson has remarked, that we owe the general adoption of the views of Mr Dalton in Great Britain. It is one of those happy inventions, which, by a singular felicity of adaptation, condenses in one view a vast mass of information, and illustrates with uncommon simplicity and precision some of the most fundamental laws of chemical action. To the practical chemist it is quite invaluable—saving him a multiplicity of calculations, which otherwise must engross a large portion of his time ; and, from the present state of chemistry, it is highly useful and interesting to the student, exhibiting, in the most striking manner, many of the most important relations of the science.*

2281. Combination in Definite proportions is the term generally employed to express the laws implied in Mr Dalton's Atomic theory, and the facts connected with it which were previously known. It includes three propositions, each of which may be stated by itself.

2282. The first of these propositions is,—*Substances that combine chemically, combine in general in certain fixed proportions.* Thus, 35.5 parts by weight of chlorine combine with 1 of hydrogen, but these bodies do not combine in any other proportions.

2283. There are many substances which can combine in more than one proportion, but no combination intermediate between these can be effected, as will be noticed more fully afterwards. The only compounds which mercury and oxygen form with each other, are in the proportion of 203 parts of the former with 8 or 16 of the latter.

2284. We cannot pass over this proposition, however, with-

* Wollaston's scale is much employed by practical chemists, where frequent calculations are required, as by it, the rule of three is performed mechanically by merely shifting a slide, according to the explanations which accompany it.

out alluding to the well known fact, that there are many cases where the combining substances can unite apparently in any proportion.   This is very well exemplified in the case of water and alcohol, or water and sulphuric acid, and also in the formation of various kinds of glass and metallic alloys.   These have been regarded by some chemists as directly opposed to the doctrine of definite proportions, but they have not usually been viewed in this light; and the apparent combination of these different bodies in unlimited proportions, is now generally considered as depending on the combination of a few definite compounds with each other.

2285. The second proposition may be stated in the following manner—*When any two substances are each of them combined with the same weight of a third substance, and the relative weights of those two substances to the third ascertained by analysis, then, if those two substances be taken in the proportion thus ascertained, and made to combine with each other, they enter into accurate combination without any redundancy of either ingredient.*   For instance, 1 part of hydrogen by weight combines with 6.12 parts of carbon and with 8 parts of oxygen, both by weight.   Agreeably, therefore, to the above proposition, 6.12 parts of carbon should enter into *accurate* combination with 8 parts of oxygen.   Accordingly, the truth of this proposition is confirmed by experiments made on purpose to ascertain the fact.   In general, therefore, it may be stated, that the proportion in which any two substances combine is accurately measured by the numbers expressing the quantities in which each of them combines with a given weight of a third substance.

2286. As this is an extremely important law, we subjoin the following table, which will place it perhaps in a more conspicuous point of view.

Olefiant Gas consists of Hydrogen 1	+ 6.12	Carbon.
Water .... Hydrogen 1	+ 8	Oxygen.
Carbonic Oxide .... Carbon	6.12 + 8	Oxygen.

Here we observe the remarkable fact that carbon and oxygen unite together in the very same proportion in which they combine with hydrogen, and the same law extends throughout the

whole series of chemical combinations.* Thus, 16.1 parts by weight of sulphur combine with 1 of hydrogen. Accordingly, we presume that the same quantity of sulphur will combine with 8 of oxygen; for, as we have already seen, 8 parts of the latter unite with 1 of hydrogen. On the same principle we infer that 35.5 parts of chlorine will combine with 8 of oxygen, both combining with the same quantity, viz. 1 part of hydrogen.

2287. In this manner, the combining quantities of the different elements and their compounds are determined. And if we take any one of them as a standard of comparison, and number the rest in relation to it, we shall be able to perceive at one glance the proportions in which different bodies combine with it, and also with each other. For, according to the law we have been illustrating, both combine together in the same proportion in which they combine with a given weight of a third substance.

2288. In drawing up tables representing the different proportions in which bodies combine together, any substance may be taken as a standard of comparison. If hydrogen be adopted for this purpose, and the proportion in which it enters into combination be taken as unity, the following numbers express the proportions in which the different substances, whose names are written opposite to them, enter into combination with 1 part by weight of hydrogen.

> *Hydrogen*........................... 1
> **Carbon**........................... 6.12
> **Oxygen**........................... 8
> **Nitrogen**........................... 14.2
> **Sulphur**........................... 16.1
> **Chlorine**........................... 35.5
> **Potassium**........................... 39.2

2289.* A single glance, then, of a table constructed in this manner communicates much information, as it shews not merely the proportions of the different substances placed below hydrogen which combine with a given weight of this element, but

---

* It must be kept in mind that this law applies only to the first combination which different bodies form with each other when they unite in more than one proportion. The reason of this will be easily understood when we shall have considered the next proposition.

also the proportions in which these bodies unite with each other. By studying the following table, which shews some of the combinations of the different substances in the preceding list, and comparing them together, the beginner will soon become familiar with the practical application of the law we have now explained.

Names of Compounds.		Component Parts.	
7.12 Hydruret of Carbon,............Hydrogen		$1+$ 6.12	Carbon.
9 Water,............................Hydrogen		$1+$ 8	Oxygen.
17.1 Sulphureted Hydrogen,.......Hydrogen		$1+16.1$	Sulphur.
36.5 Hydrochloric Acid,............Hydrogen		$1+35.5$	Chlorine.
14.12 Oxide of Carbon,.............Oxygen		$8+$ 6.12	Carbon.
22.2 Oxide of Nitrogen,............Oxygen		$8+14.2$	Nitrogen.
43.5 Oxide of Chlorine,.............Oxygen		$8+35.5$	Chlorine.
47.2 Oxide of Potassium,............Oxygen		$8+39.2$	Potassium.
55.3 Sulphuret of Potassium,.......Sulphur		$16.1+39.2$	Potassium.
74.7 Chloride of Potassium,.........Chlorine		$35.5+39.2$	Potassium.

Here also it will be observed that the numbers representing these compounds are formed by adding the numbers of the elementary substances of which they are composed. Water, for example, is represented by the number 9, being composed of 8 of oxygen and 1 of hydrogen ; chloride of potassium by 74.7, consisting of 35.5 of chlorine and 39.2 of potassium.

2290. Dr Wollaston introduced the term Chemical Equivalent to express the number representing the proportion in which bodies combine, and many others are frequently employed for the same purpose, as atomic weight or atom, combining weight, combining quantity, prime number, proportional, &c.

2291. Different chemists have introduced different standards of comparison in drawing up their tables of chemical equivalents ; oxygen, for example, being, at the present moment, represented by the different numbers, 8, 1, 10, 100. Dr Wollaston assumed oxygen as a standard of comparison in his scale of chemical equivalents, and represented it by the number 10.

2292. We now come to the third proposition included in the doctrine of Definite Proportions, viz.—*When one body combines with another in more than one definite proportion, the quantity of one of them, in the different combinations, is found to be double, triple, or some simple multiple of the smallest proportion in which it enters into combination with the other substance.* For example, if 5 parts of A be the smallest quantity which can combine with

100 of B, 10 is the next, and so on in succession, as in the following table :—

> The First combination consists of A 5 + 100 B
> ... Second .... A 10 + 100 B
> ... Third .... A 15 + 100 B
> ... Fourth .... A 20 + 100 B, &c.

2293. We shall now give a few examples illustrating the nature of this law.

> Carbonic Oxide consists of Oxygen 8 + 6.12 Carbon.
> Carbonic Acid,............... Oxygen 16 + 6.12 Carbon.
>
> Oxide of Mercury,............Oxygen 8 + 203 Mercury.
> Peroxide of Mercury,...... Oxygen 16 + 203 Mercury.
>
> Chloride of Mercury,....... Chlorine 35 5 + 203 Mercury.
> Bichloride of Mercury,..... Chlorine 71 + 203 Mercury.
>
> Nitrous Oxide,............... Oxygen 8 + 14.2 Nitrogen.
> Nitric Oxide,... .... Oxygen 16 + 14.2 Nitrogen.
> Hyponitrous Acid,.......... Oxygen 24 + 14.2 Nitrogen.
> Nitrous Acid,................ Oxygen 32 + 14.2 Nitrogen.
> Nitric Acid,................... Oxygen 40 + 14.2 Nitrogen.

2294. Many more examples might have been given, but these are quite sufficient to shew the nature of this law. We must remark, however, that in drawing up a table of chemical equivalents, or in consulting it for the purpose of ascertaining the proportions in which different bodies combine, or their composition, the student must take care to observe whether the compound consist of one equivalent of one substance united with one, or with two, or more of another; this can only be done by a reference to a list of equivalent numbers, or by a knowledge of the various compounds which different substances form with each other.

2295. There are no data by which the equivalent numbers of elementary substances can be determined, by reference to a single combination in which they may be united with another substance, whose equivalent number has been already ascertained. We must compare the proportions in which they combine with equivalent quantities of some other substances, or ascertain the different proportions in which they combine with a given weight of any individual element. Thus, if we exa-

mine the composition of corrosive sublimate, we shall find that 71 of chlorine are there combined with 203 of mercury, and, if no other compound of chlorine were known, while previous experiments had assured us that 203 represented the equivalent of mercury, we should then consider 71 as the proper equivalent number to represent chlorine. But, as it has been ascertained that 203 of mercury can combine with 35.5 of chlorine, and that the same quantity of this substance (35.5 parts) enters into combination with equivalent quantities of other substances, as 8. of oxygen, 39.2 of potassium, 1 hydrogen, &c. ; and farther, that when it deviates from this proportion, any increase in the quantity of the chlorine may be represented by a simple multiple of 35.5, as 71 ($= 35.5 \times 2$); or, that the quantity of chlorine being fixed, the other elementary substance increases in a ratio expressed by some multiple of its equivalent number, as in the peroxide of chlorine, where 32 parts of oxygen (8×4) are united with 35.5 of chlorine,—then we conclude that 35.5 is the proper equivalent number for chlorine, and that corrosive sublimate must be regarded as a compound of 2 equivalents of chlorine ($35.5 \times 2 = 71$) and 1 of mercury.

SECT. II.—ATOMIC THEORY.

2296. The propositions stated in the preceding section, are not founded on any theoretical assumptions ; their accuracy has been proved by experiment, and they must be received accordingly as matters of fact, totally independent of any hypothesis that may be proposed to account for them.

2297. No one will be inclined to believe that laws so important in their nature, and so extensive in their application, are the mere result of chance ; they must depend on some circumstances connected with the primary constitution of matter. And, as Mr Dalton proposed an explanation of these laws, which is ow considered so satisfactory that it has been adopted by the greater number of chemists, it will not be uninteresting to trace as shortly as possible the principle on which it is founded.

2298. There are few points in physical science that have been more frequently discussed than the extent to which mat-

ter is capable of being divided. According to one opinion, it was believed that the division could be carried to an indefinite length, and that there was no portion of matter, however small, that could not be reduced to still smaller portions, which were capable of being subdivided as before. Or to express it in the language generally employed, matter was regarded as being infinitely divisible.

2299. Others, again, maintained that all masses of matter are composed of atoms or particles which are in themselves indivisible, and Newton, who was among the more distinguished advocates of this opinion, considered it probable, " that the Author of Nature in the beginning formed matter in solid, massy, hard, impenetrable particles, of such 'sizes and figures as most conduced to the end for which he created them, and that these primitive particles are incomparably harder than any porous solids composed of them, so hard as never to wear away or break in pieces, no ordinary power being able to divide what had been made one in the first creation."

2300. •Such, indeed, is the view that is generally taken of this question at the present day, and it is supported by an immense mass of facts which have been discovered by the researches of modern chemists, the evidence of which appears to be quite convincing, and as strong, perhaps, as it is possible for us to have on a point which does not admit of any direct physical demonstration.

2301. These ultimate particles, then, or atoms, are regarded as having all the essential properties of matter, and are far from being mere 'mathematical points, as was at one time imagined, in which case they would not differ from space itself, as Professor Robison, long ago, so justly observed. And, as a large iron-ball may be accurately measured, and have lines traced on its surface, dividing it into various compartments, though nothing short of a very powerful mechanical force could separate these divisions from each other, so, in the same manner, it is obvious, that these ultimate particles or atoms, possessing length, breadth, and thickness, would be capable of being measured, and divisible by us also in a mathematical point of view, were our sense of vision sufficiently acute, and our instruments of investigation of a corresponding delicacy, though no force to which man can subject them, or to which they can ever be

exposed in the ordinary course of events, can reduce them to smaller parts.

2302. It is reasonable to suppose, also, that these ultimate particles may differ as much in weight, as the masses which they compose differ in specific gravity, and other properties.

2303. If, then, several elementary substances should be successively presented to each other under circumstances favourable for their combination, and combine atom to atom, they will necessarily unite together in proportions which will have a fixed and definite relation to each other.

2304. For, to take an example, if the relative weight of the ultimate particles of the following substances be correctly represented by the numbers affixed to them,

Hydrogen...................................... 1
Carbon........ .... 6.12
Oxygen...................................... 8
Sulphur...................................... 16. 1
Chlorine...................................... 35. 5

then, whenever hydrogen and carbon combine particle to particle, they will unite by weight in the ratio of 1 to 6.12, for these are the corresponding weights of their atoms.   For the same reason,

8 of oxygen will combine with 1 of hydrogen, and with 6.12 of carbon.

16.1 of sulphur, with 1 of hydrogen, with 6.12 of carbon, and with 8 of oxygen.

35.5 of chlorine, with 1 of hydrogen, with 6.12 of carbon, with 8 of oxygen, and with 16.1 of sulphur.

And thus, when a new substance is discovered, and the proportion in which it combines with any one of these substances ascertained, this becomes also the term expressing the quantity of it which combine all with the corresponding proportions of all other bodies.

2305. It will also be observed, that the same relation must be maintained whether a few or many millions of particles of matter come into play, for each particle of the one combining substance will always attach itself to a corresponding particle of the other. Thus, when one particle of hydrogen weighing 1 combines with one particle of oxygen weighing 8, these bodies unite together in the same relative proportion as when a thousand particles of hydrogen weighing 1000, unite with one thousand particles of oxygen weighing 8000—1 : 8 : : 1000 : 8000.

2306. Hence, then, as a relation has been found to exist in the proportion in which masses of matter combine, (See Proposition II.), such as has just been explained in regard to their particles, it must lead us to the conclusion that all bodies are composed of atoms or ultimate particles, whose union with each other in the manner described is the cause of the law found to regulate the proportions in which they combine ; and though we may never be able to tell the exact weight of any single particle, nor the number of particles in any individual mass, still, when we compare the proportions in which bodies enter into combination, we count, according to Mr Dalton's views, the united weights of a given number of the particles of one kind of matter, which combine with a corresponding number of particles of other substances, and consequently these numbers must express the relative weights of the particles themselves.

2307. We can also perceive, adopting this atomic view of the constitution of matter, why there still should be a relation between the quantities in which bodies combine, when they are capable of uniting in several fixed or definite proportions. If we find that a particle of any one substance can combine with more than one particle of another, then, supposing the first quantity to be fixed, the proportion in which the other enters into combination must be exactly double, triple, or some other simple multiple of the smallest quantity that exists in the first combination. For whatever increase there may be in the proportion of this substance, it must always take place particle by particle. No smaller or intermediate quantity can enter into combination. Nor could it indeed be procured, for, according to the definition, these particles are indivisible.

2308. While the general accuracy of the propositions connected with the atomic theory of Dalton has been universally admitted, still there are many who consider that we are not yet sufficiently informed as to the constitution of matter to be enabled to affirm that each individual atom which is to us as an indivisible particle of matter, may not consist of groups of atoms of still smaller dimensions. Still, however, so long as they enter into distinct and definite combinations only in certain fixed proportions, and are separated again in the same manner, they perform all the functions of an indivisible atom, whatever speculations may be entered into as to their precise constitution.

SECT. III.—THEORY OF VOLUMES.

2309. An interesting discovery was made by Gay-Lussac with regard to the combination of gases. He found that when they unite together, the bulk of the one always bears a simple ratio to the bulk of the other. Thus one measure of chlorine combines with an equal bulk of hydrogen, half a measure of oxygen combines with one of hydrogen and one of nitrogen; one measure of nitrogen again combines with three of hydrogen. It will also be obvious, that when they combine in more than one proportion, the quantity of the combining substances is increased by some simple multiple of the smallest quantity of it which enters into the first combination; a proposition which flows, indeed, from the laws already illustrated, though established experimentally independent of it. These general laws have received the appellation of the Theory of Volumes, and they agree strictly with the Doctrine of Definite Proportions, as will be seen in the following table :

						Volume.		Atomic weight.
Oxygen,	.	.	.	.	.	▭	.	8
Hydrogen,	.	.	.	.	.	□	.	1
Chlorine,	.	.	.	.	.	□	.	35.5

Here, the first column represents the proportion in which these different gases combine with each other by volume, while the second represents their chemical equivalents by weight. It is obvious, therefore, that the numbers in the last column indicate the comparative weight of the volumes of the different gases in the first column, and that half a volume of oxygen unites with one of hydrogen, and one of chlorine, in the first combination which it forms with these bodies, while hydrogen will combine with an equal volume of chlorine. These observations shew the necessary connexion that exists between the theory of volumes and the equivalents of different substances by weight; and the student will find it important to study this subject in operating with gases. A number of tables have been drawn up, in which the composition of all the gases by weight and by volume are expressed in figures, which may be consulted with great advantage. In the table which follows, the composition of a number of important compounds is stated with their equivalents both by weight and by volume, according to the

most recent investigations which have been greatly extended, since Gay-Lussac first directed his attention to the subject, particularly by Mitscherlich, who has pointed out several substances whose equivalents by volume vary more than those which had been previously examined.

2310. *Table of Gaseous Substances.*

GASES AND VAPOURS.	Equiva-lents by bulk.	Equiva-lents by weight.	Symbol.	Number of eq. which express the sp. gr. Hydrogen=1.
Oxygen, (half a measure)..............		8	O	2
Sulphur, (a third of a measure).......		16.1	S	3
Phosphorus,.............................		15.7	P	2
Arsenic,..............................		37.7	As	2
Arsenious Acid,.........................		99.4	O^3As^2	2
Hydruret of Carbon,...................		7	HC	2
Hydrogen, (a whole measure)........		1	H	1
Water,....		9	OH	1
Nitrogen,.............................		14.2	N	1
Oxide of Nitrogen,...................		22.2	ON	1
Carbon (hypothetical),.............		6.12	C	1
Carbonic Oxide,......................		14.12	OC	1
Carbonic Acid,.......................		22.12	O^2C	1
Bihydruret of Carbon,...............		8.12	H^2C	1
Cyanogen,.........		26.44	C^2N	1
Sulphurous Acid,.....................		32.1	O^2S	1
Sulphuric Acid (anhydrous),........		40.1	O^3S	1
Hydrosulphuric Acid,................		17.1	HS	1
Chlorine,.............................		35.5	Cl	1
Iodine,...............................		126.5	I	1
Bromine,...		78.4	Br	1
Binoxide of Nitrogen, (2 measures)		30.2	O^2N	½
Ammonia,.............................		17.2	H^3N	½
Hydrocyanic Acid,...................		27.44	HC^2N	½
Hydrochloric Acid,..................		36.5	HCl	½
Hydriodic Acid,......................		127.5	HI	½
Hydrobromic Acid,...................		79.4	HBr	½
Arsenurated Hydrogen,..............		78.4	H^3As^2	½
Mercury,.........		203	Hg	½
Chloride of Mercury,................		238.5	ClHg	½
Bichloride of Mercury,..............		274.	Cl^2Hg	½
Atmospheric Air,....................		36.4	$\cdot N^2$	¾

2310. Others of less importance have also been examined, or the sulphuret, bromide and bibromide, and the biniodide of mercury, and some more compounds of arsenic.

Sect. IV. Isomerism and Isomorphism.

2311. The above terms have been introduced to embody the facts connected with the relations of Isomeric and Isomorphous substances.

2312. Of late years, it has been shewn that the same elements united in the same ratios may produce very different compounds, according to the manner in which they are united, and such compounds are said to be Isomeric, being composed of the same parts (ισοσ equal and μερος a part). When the atomic weight of the compounds is the same, they are called more especially Metameric compounds. But when the atomic weight is different, they are said to be Polymeric. Thus $AB + CD$, and $AC + CD$ are isomeric. But $AB + CD$ and $2 (AB + CD)$, each formula representing a single equivalent, are polymeric.

2313. Isomorphous Bodies are substances which are supposed to have essentially the same form (ισοσ equal and μορφη form), as they can mutually replace each other in combinations, without any change of form taking place. In such compounds, accordingly, one ingredient can be taken away, and replaced by another which is isomorphous with it, the form of the compound being still the same.

2314. Gay-Lussac discovered the isomorphous properties of different crystalline substances ; and Mitscherlich has greatly extended this important subject.

2315. The following group is taken from his researches.[*]

I. Group.
Silver.
Gold.

II.
Arsenious Acid (dimorphous).
Protoxide of Antimony.

III.
Alumina.
Peroxide of Iron.

Peroxide of Chromium.
Peroxide of Manganese.

IV.
Phosphoric Acid.
Arsenic Acid.

V.
Sulphuric Acid.
Selenic Acid.
Chromic Acid.

[*] From Liebig's First Elements.

Manganesic Acid.

        VI.

Permangnnesic Acid.

Perchloric Acid.

        VII.

Salts of Potash.

Salts of Ammonia with 1 atom of water

        VIII.

Oxide of Silver.

Soda.

        IX.

Baryta.

Strontia.

Lime (in arragonite).

Peroxide of Lead.

        X.

Lime.

Magnesia.

Protoxide of Iron.

Protoxide of Manganese.

Oxide of Zinc.

Oxide of Nickel.

Oxide of Cobalt.

Oxide of Copper.

Oxide of Lead (in plumbocalcite.)

2316. The great practical points to be attended to in connection with the doctrine of isomorphism, are included in the following propositions.

1. Isomorphous elements produce compounds having similar forms, where each enter into combination with the same number of atoms of the same bodies, these being also arranged in the same way.

2. Isomorphous compounds are inferred to have a similar composition, and the atoms are considered to be arranged in the same manner in each.

2317. Considerable difficulty is still experienced as to the action of minute quantities of matter in some combinations, where it may not exceed a $\frac{1}{10,000}$th part of the other ingredients, and still produces the most marked effect upon the characters of the compounds. No satisfactory explanation has yet been offered, but some electrical action is suspected to be induced.

Sect. V. Explanation of a New System of Diagrams for facilitating the Study of Chemistry.

2318. In examining the chemical relations of different substances, it will facilitate greatly the progress of the beginner to represent by diagrams, and in equivalent numbers, the changes that take place in all the more complicated cases of chemical action.

2319. Diagrams for this purpose were first employed by Dr Cullen, and afterwards by Bergman, since which they have been very frequently used by succeeding chemists. When the doctrine of definite proportions began to be generally under-

stood, and a series of equivalent numbers had been arranged, a corresponding system of notation was soon afterwards introduced, the proportion of materials employed in different operations, and of the resulting products, being also expressed in equivalent numbers.

2320. In following out this plan, it appeared to me that a series of diagrams, better adapted to the present state of the science, could be constructed. The names of the substances that react on each other, and the numbers representing the necessary proportions, are placed on the left, one above the other. When any of these are compounds which are decomposed, brackets proceeding from them enclose the names of the elements or proximate principles of which they consist. Lines are traced from the numbers representing the quantities of each of these substances, drawing them from the left to the right. Those that proceed from the different elements, or compounds that combine together, terminate in a common point, and opposite these, towards the right, are placed the names of the products, and their quantities. The annexed figure represents the decomposition that takes place during the preparation of muriatic acid gas, according to this plan.

Fig. 236.

Substances Decomposed.	Component Parts.		Resulting Products.
49.1 Aqueous Sulphuric Acid,	Hydrogen	1	36.5 Hydrochloric Acid Gas.
	Oxygen...	8	
	Dry Acid..40.1		
60 Chloride of Sodium, ...	Chlorine..35.5		
	Sodium 23.5		71.6 Sulphate of Soda.
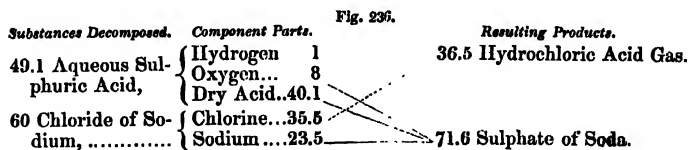
2321. The decomposition of nitrate of ammonia by heat, when it is resolved into oxide of nitrogen and water, may be shewn in the following manner :—

Fig. 237.

Before Decomposition.	Elementary Composition.		After Decomposition.
	Oxygen...	8	22.2 Oxide of Nitrogen.
	Oxygen...	8	22.2 Oxide of Nitrogen.
54.2 Nitric Acid,....	Oxygen...	8	
	Oxygen...	8	
	Oxygen...	8	
	Nitrogen..14.2		
	Nitrogen..14.2		
17.2 Ammonia, ...	Hydrogen	1	9 Water.
	Hydrogen	1	9 Water.
	Hydrogen	1	9 Water.
71.4 Nitrate of Ammonia,.........71.4			71.4
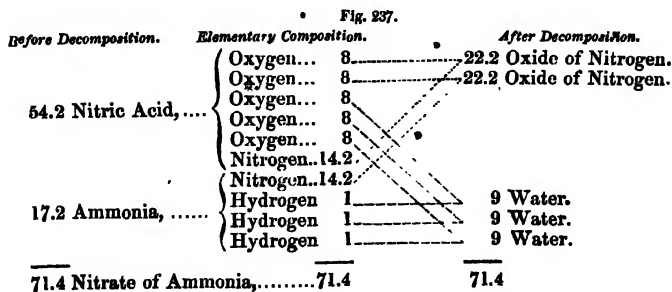
2322. When a number of equivalents of one element react upon one or more of another, the manner in which they are expressed may be frequently contracted with advantage. Thus, in the preparation of sulphurous acid by the action of metallic mercury on sulphuric acid, we may express the composition of the latter, and the production of the sulphurous acid, in either of the following ways.

Fig. 238.

1.

$$
\text{40.1 Sulphuric Acid} \begin{cases} \text{Sulphur} & 16.1 \cdots \cdots \cdots \quad \text{32.1 Sulphurous Acid.} \\ \text{Oxygen} & 8 \cdots \\ \text{Oxygen} & 8 \cdots \\ \text{Oxygen} & 8 \quad \quad \quad \text{8 Oxygen withdrawn by the Mercury.} \end{cases}
$$

2.

$$
\text{40.1 Sulphuric Acid} \begin{cases} \text{Sulphurous Acid 32.1} \ldots \ldots \ldots \text{32.1 Sulphurous Acid.} \\ \text{Oxygen} \ldots \ldots \ldots \quad 8 \quad \quad \text{8 Oxygen withdrawn, \&c.} \end{cases}
$$
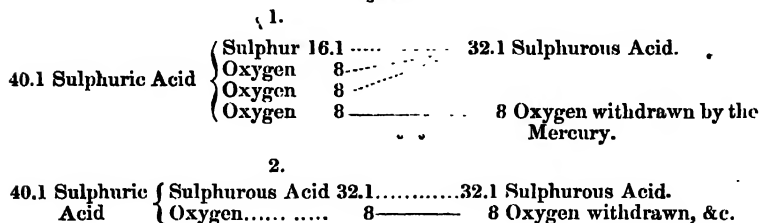
2323. These diagrams may be rendered still more useful by changing the character of the line, so as to express the different conditions in which the products of any reaction are obtained. When they are gaseous, the lines may be dotted, as in those pointing to hydrochloric acid gas and oxide of nitrogen in the first two diagrams. When they are liquid, or retained in solution, lines composed of many smaller lines may be made to indicate this circumstance, as in those pointing to the quantity of water produced during the preparation of the oxide of nitrogen. And when any substance is obtained in the solid form, a plain line may be used.

2324. The great advantage, then, of these diagrams is, that in studying them, the eye at once presents to the mind a group of facts, which would otherwise require a very long statement, while the facts are represented in a clearer manner than by a mere verbal description. The attention of the student is at the same time more forcibly arrested. A more distinct impression is made upon his mind, and he can afterwards recall it by a single glance, when studying or conducting chemical operations. Diagrams constructed in the manner I have described are applicable in all cases of chemical action, and the following brief summary shews the different circumstances which they may be made to express in every process or experiment which they are employed to illustrate.

1. The names and quantities of the different materials that are used.

2. Their composition, and the relative quantities of their component parts.

3. The manner in which they arrange themselves during the reaction that takes place.

4. The names and the quantities of the resulting products.

5. The condition in which the different products are obtained, whether solid, liquid, or gaseous, as indicated by the character of the lines.

6. The condition of the substances that are employed might also be expressed by some mark prefixed to their names, or in the case of compound substances which are decomposed, by having the lines of which the brackets are composed formed in the manner described in a preceding paragraph (2323); or, types of a different character might be used in printing their names, according as they might be solid, liquid, or gaseous.

SECT. VI.—CHEMICAL NOMENCLATURE.

2325. Chemistry has extended so much of late years, and so many anomalies have crept into its nomenclature, that the whole subject demands revision, and to be adapted to the present state of science.

2326. The names of elements are usually derived from some of their more characteristic properties.

2327. The terms BINARY, TERNARY, QUATERNARY COMPOUNDS, &c., refer in this work to the number of elements or proximate principles in a compound, not to the number of atoms.

2328. In binary compounds of oxygen, chlorine, iodine, bromine, and fluorine, which are not acid, the name of the compound terminates in IDE, as in oxide of zinc, chloride of mercury, and iodide of lead. A similar termination is given to cyanogen, though some give it the terminating syllables URET.

2329. In binary compounds of all other substances, the name terminates in URET, as in hydruret of carbon, sulphuret of iron, potassiuret of antimony.

2330. The number of atoms in the first element or proximate principle mentioned in any compound, is usually indicated by a

Latin numeral, as BIS, TER, QUATER, &c., and the number of atoms in the second by a Greek numeral, as DIS, TRIS, TETRAKIS. No prefixture is made when the compound consists of 1 atom of each ingredient, except where this is emphatically referred to, when it is termed a proto-compound.

2331. To the rules in the preceding paragraph there are many exceptions. Thus protoxide and deutoxide are familiarly used as substitutes for oxide and binoxide.

2332. DEUTOXIDE is frequently used to signify a compound of three atoms of oxygen with two of metal, as in the deutoxide of manganese, and deutoxide of lead; but the term sesqui is now more frequently preferred in such cases.

2333. The prefixture PER indicates an oxide containing the largest quantity of oxygen that can exist in any oxide formed of the same materials.

2334. OXACIDS are acids containing oxygen, and the relative number of atoms of oxygen, where different acids are produced by the same element with this substance, are indicated by the prefixtures or by the termination of the name.

2335. Ic generally indicates the compound with most oxygen, as in sulphuric acid.

2336. Ous indicates a smaller quantity of oxygen, as in sulphurous acid.

2337. HYPO indicates a smaller quantity of oxygen than is found in compounds to whose name it is prefixed, as in hyposulphuric acid and hyposulphurous acid.

2338. SUB is occasionally employed to denote an intermediate degree of oxidation, as in subsulphurous acid, which contains less than sulphurous, but more than hyposulphurous acid, according to Dr Thomson.

2339. PER is used where acids have been discovered containing still more oxygen than those whose names terminate in ic, as perchloric acid.

2340. HYPER where a still larger quantity is observed.

2341. HYDRACIDS are acids containing hydrogen; their names are also made to terminate in IC, as hydriodic acid, composed of hydrogen and iodine.

2342. AQUEOUS is a term now coming into very general use in designating definite combinations with water; the word HYDRATE has long been employed for the same purpose: a prefix-

ture is made when there is more than one atom, as in binaqueous, terhydrate.

2343. ALCOATES are definite compounds of alcohol and various saline substances ; they were discovered by Professor Graham.

2344. SESQUI is a prefixture applied not only to oxides, but also to other compounds where two atoms of one substance are united with three of another, as in the sesqui-carbonate of soda, where two of soda are united with three atoms of carbonic acid All such combinations may be considered as constituted of two compounds, in one of which the ingredients are combined atom to atom, and in the other in the proportion of two to one. In the example quoted, the sesqui-carbonate of soda may be regarded as a compound of the carbonate and bicarbonate of soda. The term HEMI has been proposed by Mr Lunn as a prefixture in similar cases.

2345. The term SALT is applied to a very extensive range of compounds, where acids are combined with oxides or other compounds having similar properties, as ammonia. The oxide, ammonia, or other substance united with the acid, is called a BASE, or SALIFIABLE BASE.

2346. The NAMES OF SALTS are composed of the names of the acid and base.

2347. ATE is the terminating syllable given in such cases to the name of an acid ending in IC, as in sulphate of potassa, composed of sulphuric acid and the base potassa.

2348. ITE is the terminating syllable when the name of the acid ends in OUS, as in sulphite of potassa, which consists of sulphurous acid and potassa.

2349. A SUPERSALT indicates that the properties of the acid predominate, without reference to the precise composition, as in the supertartrate of potassa.

2350. A SUBSALT indicates that the qualities of the base predominate, as in the sub-borate of soda.

2351. A NEUTRAL SALT expresses that the compound has none of the characteristic properties either of the acid or base, as in the sulphate of potassa ; the term neutral is often omitted.

2352. The three last prefixtures being used only in a general sense, other terms are necessary to express the precise constitution of saline combinations.

2353. No PREFIXTURE is in general made when the salt is

composed of one atom of acid and one of base, the latter being composed of one atom of metal and one of oxygen, if it be an oxidated metal. The term proto, however, is occasionally prefixed to express this more specifically, as in protosulphate of iron for sulphate of iron.

2354. In salts of the common metals, the name of the metal is substituted for the name of the base, where there is but one atom of oxygen united with one of metal, as in sulphate of iron, which is more correctly termed sulphate of the oxide of iron.

2355. Bis, Ter, Quater, &c. are prefixed where 2, 3, or 4 atoms of acid are combined with 1 of base, as in the bisulphate of soda, and quadrisulphate of potassa.

2356. Dis, Tris, Tetrakis, &c. are prefixed where 1 atom of acid is united with 2, 3, 4, or more atoms of base, as in the dichromate of lead, and trisnitrate of bismuth.

2357. A DOUBLE PREFIXTURE is necessary, when there is more than 1 atom of oxygen in the base, as well as an unequal number of atoms of acid and base, as in the bipersulphate of mercury, where *bi* expresses 2 atoms of acid, and *per* that the mercury is in the form of a peroxide. It may also be termed still more precisely bisulphate of binoxide of mercury.

2358. Double Salts are compounds where one salt is combined with another, as in the tartrate of potassa and soda, regarded as a compound of tartrate of potassa and tartrate of soda. The term Triple Salt is also applied to such combinations, the name being derived from the three different ingredients present.

2359. Haloid Salts differ much in their composition from the preceding substances; the term is applied to compounds of the metals with bodies such as chlorine, iodine, bromine, fluorine, and cyanogen; but not to compounds containing oxygen and sulphur. The term is derived from αλς, salt, and ειδος, form, as they are similar in constitution to common salt.

2360. Haloid salts can combine with different acids, oxides, common salts, and also with each other.

2361. Sulpho Salts include a series of compounds which have been particularly attended to only of late years; they consist of compounds, both of which contain sulphur. Compounds of hydrogen, carbon, or metals with sulphur, when combined with other compounds formed of metals and sulphur, constitute this group of salts. In the common salts, a large proportion of

which contain oxygen, this element is found both in the acid and in the base ; thus, in the phosphate of soda, it is associated with phosphorus in phosphoric acid, and with sodium in the soda ; and hence such combinations are termed OXY-SALTS. In the sulpho-salts, sulphur plays the same part, forming with one element an acid, and with the other a salifiable base.

2362. AMMONIURETS are compounds containing ammonia and salifiable bases, or other substances not acid.

2363. The prefixture *ammoniaco*, or *ammonia*, is frequently put before salts, where this substance has been added in sufficient quantity to combine both with the acid and the base.

2364. The following view of the nomenclature of several compounds, will shew the system of nomenclature proposed by Dr Hope, founded upon the suggestion of Dr Thomson, that the Greek adverbial numerals should be employed in designating the number of eqs. of base, and the Latin in expressing the number of eqs. of acid. In the Encyclopædia Metropolitana, some interesting details will also be found in reference to chemical nomenclature.

Dr Hope has also proposed that the interweaving of the Greek and Latin numerals in the same word should be avoided, and that the prefixtures of proto, per, sub, and super, should be discontinued, as equally unnecessary, and apt to lead to a confusion of terms. Were these proposals generally adopted, they would certainly simplify much the present state of chemical nomenclature.

TABLE I.

Atom of Metal.		Atom of Oxygen.	Oxide.
1	+	1	Oxide of Metal.
1	+	2	Bis Oxide of Metal.
1	+	3	Ter Oxide of Metal.
1	+	4	Quater Oxide of Metal.
2	+	1	Dis Oxide of Metal.
3	+	1	Tris Oxide of Metal.
4	+	1	Tetrakis Oxide of Metal.
2	+	3	Dis Ter Oxide of Metal.
2	+	5	Dis Quinquoxide of Metal.

TABLE II.

Oxide.		Acid Sulphuric.	Compound Salt.
1	+	1	Sulphate of Metal
1	+	2	Bis Sulphate of Metal.
1	+	3	Ter Sulphate of Metal.
1	+	4	Quater Sulphate of Metal.
2	+	1	Dis Sulphate of Metal.
3	+	1	Tris Sulphate of Metal.
4	+	1	Tetrakis Sulphate of Metal.
Bis Oxide.			
1	+	1	Sulphate of Bis Metal.
1	+	2	Bis Sulphate of Bis Metal.
2	+	1	Dis Sulphate of Bis Metal.
Ter Oxide.			
1	+	1	Sulphate of Ter Metal.
1	+	2	Bis Sulphate of Ter Metal.
1	+	3	Ter Sulphate of Ter Metal.
2	+	1	Dis Sulphate of Ter Metal.
Dis Oxide.			
1	+	1	Sulphate of Dis Metal.
1	+	2	Bis Sulphate of Dis Metal.
2	+	1	Dis Sulphate of Dis Metal.
Tris Oxide.			
1	+	1	Sulphate of Tris Metal.
1	+	2	Bis Sulphate of Tris Metal.
2	+	1	Dis Sulphate of Tris Metal.
Dis Ter Oxide.			
1	+	1	Sulphate of Dis Ter Metal.
1	+	2	Bis Sulphate of Dis Ter Metal
2	+	1	Dis Sulphate of Dis Ter Metal

Section VII.

2365. In the present state of Chemistry, symbols are as important as figures in arithmetic. Without them it is impossible to follow with distinctness and precision the varied changes that accompany chemical action, or even to express with facility te constitution of compounds. They afford, also, great advantages to the student. Those adopted in this work are explained immediately after the title-page.

2366. In examining symbols, the beginner must recollect, that

in numerous cases, if not in all, it is impossible to tell in what manner the elements of a compound may be associated together, though the quantity of each may have been carefully and accurately determined by experimental investigation. Hence the symbolic expression of any compound may be very various according to the theoretical views entertained as to the manner in which they are arranged. Thus, if real sulphuric acid and ammonia be brought in contact in the gaseous condition, a compound is produced in which there are 1 eq. of sulphur, 3 of oxygen, 1 of nitrogen, and 3 of hydrogen.

It may be expressed, then, symbolically, in many different ways:—

1. SNO^3H^3

2. $SN + 3 \cdot H =$ Sulphuret of nitrogen + 3 of water.

3. $:S + NH^3 =$ Sulphate of ammonia.

4. $:S + NH^2 + \cdot H =$ Aqueous sulphate of amide, &c. &c.

2366. AMIDE is the name given to a compound which has not hitherto been insulated. The term Amidogen is considered preferable, and then its compounds may be termed AMIDES.

Again, when hydrosulphuric acid is brought into combination with ammonia, these materials may produce hydrosulphate of ammonia; or, as many are now disposed to view the compound, it may be termed sulphuret of ammonium, and a compound in which the elements of water and ammonia are present, may contain these in the form of oxide of ammonium. The term AMMONIUM is applied to a compound which, like amidogen, has never been insulated, but is supposed to be produced in numerous cases where ammonia acquires hydrogen when brought in contact with other substances. Thus,—

$HS + NH^3 =$ Hydrosulphate of ammonia, or

$S + NH^4 =$ Sulphuret of ammonium.

$\cdot H + NH^3 =$ Hydrate of ammonia.

$\cdot + NH^4 =$ Oxide of ammonium.

2367. Even where the sulphuric acid enters into combination, we have no proof of the manner in which its elements finally arrange themselves in the new combination. For instance, if it act with soda, it may produce merely sulphate of soda; or, it may decompose the soda and attract its oxygen, forming SULPHATOXYGEN, as the imaginary compound thus produced has

R r

been termed, which combines with the soda. The following symbolic expressions accordingly present themselves :—

$O^4 + SNa =$ Quadroxide of the sulphuret of sodium.

$:S + \cdot Na =$ Sulphate of soda.

$\cdot:S + Na =$ Sulphatoxide of sodium.

In the same manner, as Professor Graham remarks, aqueous sulphuric acid, which is now frequently termed sulphate of water, may also be termed sulphatoxide of hydrogen.

$\cdot H :S =$ Aqueous sulphuric acid ;

$:S \cdot H =$ Sulphate of water, or

$\cdot:SH\cdot =$ Sulphatoxide of hydrogen, the combination being considered, when this arrangement is adopted, analogous to the sulphatoxide of sodium.

2368. The combinations of water are at present a source of great interest, as from the investigations of Professor Graham, more particularly it performs in many saline combinations the functions of a base, replacing oxides or other substances, and being retained in this condition with a much greater power of attraction than is observed in water of crystallization, which may be expelled in general by a moderate heat.

Sect. VIII.—Table of Equivalents.

2369. In the table of Equivalent Numbers, I have preferred a systematic to an alphabetical arrangement, as it will be more interesting to those who study it with the view of making themselves more familiar with the laws that regulate the proportions in which bodies combine, and the constitution of the more important compounds.

2370. It is much to be regretted, that it has not been usual for chemists to express the composition of all these substances in the same manner, numerous differences of nomenclature may be observed in different works on chemistry, dependent partly upon the state of the science, which must often prove very perplexing to the beginner, especially when he finds some compounds represented as consisting of one equivalent of one substance, and an equivalent and a half of another, a mode of expression common in some of our best treatises on Chemistry, and which custom has forced many to adopt, though it is certainly very

desirable that another mode of expression should be preferred, more consistent with what the student is taught on commencing the study of chemistry.*

* In the annexed table, the first line in each example shews the commo method of representing the constitution of a few cases of such combinations, and the second line (and third line also in the two first examples) gives a corrected view of their composition.

Ex. 1. DEUTOXIDE (Terdinoxide or Sesquioxide) OF MANGANESE.

$$1 \text{ Equiv. Manganese } 27.7 + 1\tfrac{1}{2} \text{ Oxygen } 12 = 39.7$$
Corrected view.
$$2 \dots\dots\dots \text{ Manganese } 55.4 + 3 \text{ Oxygen } 24 = 79.4$$
or,
$$1 \dots\dots\dots \text{ Oxide } \quad 35.7 + 1 \text{ Binoxide } 43.7 = 79.4$$

Ex. 2 PEROXIDE (or Sesquioxide) OF IRON.

$$1 \text{ Equiv. Iron } \quad . \quad 28 + 1\tfrac{1}{2} \text{ Oxygen } 12 = 40$$
Corrected view.
$$2 \dots\dots\dots \text{ Iron } \quad . \quad 56 + 3 \text{ Oxygen } 24 = 80$$

Chemistry has extended so much of late years, and so many anomalies have crept into its nomenclature, that the whole subject demands revision, and to be adapted to the present state of science.

CLASS I.—SIMPLE SUBSTANCES NOT METALLIC, AND THEIR COMBINATIONS WITH EACH OTHER.

*** The large figures express the *number* of Equivalents, and the small figures their Weight. The Italic Capitals are used as provisional symbols. See page 644.

	Symbol.	Atomic Weight.	Composition.				
OXYGEN, . . .	O or ·	8					
HYDROGEN, . . .	H	1					
Oxide, ...	·H	9	**1** Oxygen	8	+**1** Hydrogen	1	
Binoxide, . . .	:H	17	**2** Oxygen	16	+**1** Hydrogen	1	
NITROGEN, . . .	N	14.2					
Oxide, ...	·N	22.2	**1** Oxygen	8	+**1** Nitrogen	14.2	
Binoxide, . . .	:N	30.2	**2** Oxygen	16	+**1** Nitrogen	14.2	
Hyponitrous Acid, . .	⋮N	38.2	**3** Oxygen	24	+**1** Nitrogen	14.2	
Nitrous Acid, . .	::N	46.2	**4** Oxygen	32	+**1** Nitrogen	14.2	
Nitric Acid, . . .	::N	54.2	**5** Oxygen	40	+**1** Nitrogen	14.2	
Binaqueous Nitric Acid,	2·H+::N	72.2	**2** Water	18	+**1** Nitric Acid	54.2	
Atmospheric Air, . .	·N²	36.4	**1** Oxygen	8	+**2** Nitrogen	28.4	
Amidogen, or Amide? .	NH²	16.2	**1** Nitrogen	14.2	+**2** Hydrogen	2	
Ammonia, . . .	NH³	17.2	**1** Nitrogen	14.2	+**3** Hydrogen	3	
Ammonium, · . .	NH⁴	18.2	**1** Nitrogen	14.2	+**4** Hydrogen	4	
SULPHUR, . . .	S	16.1					
Sulphurous Acid, . .	:S	32.1	**2** Oxygen	16	+**1** Sulphur	16.1	
Sulphuric Acid, . .	⋮S	40.1	**3** Oxygen	24	+**1** Sulphur	16.1	
Aqueous Sulphuric Acid,	·H⋮S	49.1	**1** Water	9	+**1** Sulphuric Acid	40.1	
Hyposulphurous Acid, .	:S²	48.2	**2** Oxygen	16	+**2** Sulphur	32.2	
Hyposulphuric Acid, .	::S²	72.2	**5** Oxygen	40	+**2** Sulphur	32.2	
Hydrosulphuric Acid, .	HS	17.1	**1** Hydrogen	1	+**1** Sulphur	16.1	
Bisulphureted Hydrogen,	S²H	33.2	**2** Sulphur	32.2	+**1** Hydrogen	1	
Nitrosulphuric Acid, .	O⁴SN	62.3	**4** Oxygen	32	+**1** Sulphur	16.1	
					+**1** Nitrogen	14.2	
SELENIUM, . . .	Se	40					
Oxide, . . .	·Se	48	**1** Oxygen	8	+**1** Selenium	40	
Selenious Acid, . .	:Se	56	**2** Oxygen	16	+**1** Selenium	40	
Selenic Acid, . . .	⋮Se	64	**3** Oxygen	24	+**1** Selenium	40	
Selenureted Hydrogen,	HSe	41	**1** Selenium	40	+**1** Hydrogen	1	
PHOSPHORUS, . . .	P	15.7					
Hypophosphorous Acid, .	·P²	39.4	**1** Oxygen	8	+**2** Phosphorus	31.4	

	Symbol.	Atomic Weight.	Composition.			
Phosphorous Acid, . .	∴P²	55.4	**3** Oxygen	24	+ **2** Phosphorus	31.4
Phosphoric Acid, . .	⠔P²	71.7	**5** Oxygen	40	+ **2** Phosphorus	31.4
Phosphureted Hydrogen,	H³P²	34.4	**2** Phosphorus	31.4	+ **3** Hydrogen	3
CARBON, ...	C	6.12				
Carbonic Oxide, . .	·C	14.12	**1** Oxygen	8	+ **1** Carbon	6.12
Carbonic Acid, . . .	:C	22.12	**2** Oxygen	16	+ **1** Carbon	6.12
Hydruret of Carbon, .	HC	7.12	**1** Hydrogen	1	+ **1** Carbon	6.12
Bihydruret of Carbon, .	H²C	8.12	**2** Hydrogen	2	+ **1** Carbon	6.12
Bisulphuret of Carbon,	S²C	38.32	**2** Sulphur	32.2	+ **1** Carbon	6.12
BORON, ...	B	11				
Boracic Acid, . . .	∴B	35	**3** Oxygen	24	+ **1** Boron	11
CHLORINE, . . .	Cl	35.5				
Hypochlorous Acid, .	·Cl	43.5	**1** Oxygen	8	+ **1** Chlorine	35.5
Chlorous Acid, . .	⠔Cl	67.5	**4** Oxygen	32	+ **1** Chlorine	35.5
Chloric Acid, . .	∴Cl	75.5	**5** Oxygen	40	+ **1** Chlorine	35.5
Perchloric Acid, . .	⠔∴Cl	91.5	**7** Oxygen	56	+ **1** Chlorine	35.5
Hydrochloric Acid, . .	HCl	36.5	**1** Hydrogen	1	+ **1** Chlorine	35.5
Quadrochloride of Nitrogen,	Cl⁴N	156.2	**4** Chlorine	142	+ **1** Nitrogen	14.2
Chloronitrous Gas, .	Cl²:N	101.2	**2** Chlorine	71	+ **1** Binoxide N.	30.2
Dichloride of Sulphur, .	ClS²	67.7	**1** Chlorine	35.5	+ **2** Sulphur	32.2
Sesquichloride of Phosphorus,	Cl³P²	137.9	**3** Chlorine	106.5	+ **2** Phosphorus	31.4
Hydrocarburet of Chlorine,	H²C⁷Cl	49.74	**2** Hydrogen	2	+ **2** Carbon	12.24
					+ **1** Chlorine	35.5
Chlorocarbonic Acid, .	Cl·C	49.7	**1** Chlorine	35.5	+ **1** Carb. Oxide	14.2
Terchloride of Boron, .	Cl³B	117.5	**3** Chlorine	106.5	+ **1** Boron	11
IODINE, ...	I	126.5				
Iodic Acid, . . .	∴I	166.5	**5** Oxygen	40	+ **1** Iodine	126.5
Periodic Acid, . .	⠔∴I	182.5	**7** Oxygen	56	+ **1** Iodine	126.5
Hydriodic Acid, . .	HI	127.5	**1** Hydrogen	1	+ **1** Iodine	126.5
Teriodide of Nitrogen, .	I³N	393.7	**3** Iodine	379.5	+ **1** Nitrogen	14.2
Chloriodic Acid, .	ClI ?	162	**1** Chlorine	35.5	+ **1** Iodine	126.5
Terchloride of Iodine, .	Cl³I ?	233	**3** Chlorine	106.5	+ **1** Iodine	126.5
BROMINE, . . .	Br	78.4				
FLUORINE, . . .	F	18.7				
Hydrofluoric Acid, . .	HF	19.7	**1** Hydrogen	1	+ **1** Fluorine	18.7
Terfluoride of Boron,* .	F³B	67.1	**3** Fluorine	56.1	+ **1** Boron	11
Terfluoride of Silicum,†	F³Si ?	78.1	**3** Fluorine	56.1	+ **1** Silicum	22 ?

CLASS II.—METALS AND THEIR COMBINATIONS WITH NON-METALLIC SUBSTANCES.

ORDER I.—KALIGENOUS METALS.

	Symbol.	Atomic Weight	Composition.			
POTASSIUM,	K	39.2				
Chloride,	ClK	74.7	1 Chlorine	35.5	+ 1 Potassium	39.2
Iodide,	IK	165.7	1 Iodine	126.5	+ 1 Potassium	39.2
Bromide,	BrK	117.6	1 Bromine	78.4	+ 1 Potassium	39.2
Fluoride,	FK	57.9	1 Fluorine	18.7	+ 1 Potassium	39.2
Sulphuret,	SK	55.3	1 Sulphur	16.1	+ 1 Potassium	39.2
Bisulphuret,	S²K	71.4	2 Sulphur	32.2	+ 1 Potassium	39.2
Oxide (Potassa)	·K	47.2	1 Oxygen	8	+ 1 Potassium	39.2
Peroxide	⫶K	63.2	3 Oxygen	24	+ 1 Potassium	39.2
POTASSA, salts of						
Acetate,	A·K	98.68	1 Acetic Acid	51.48	+ 1 Potassa	47.2
Benzoate,	B·K	161.88	1 Benzo. Acid	114.68	+ 1 Potassa	47.2
Carbonate,	⫶C·K	69.32	1 Carbo. Acid	22.12	+ 1 Potassa	47.2
Bicarbonate,	2⫶C+·K	91.44	2 Carbo. Acid	44.24	+ 1 Potassa	47.2
Cr. 1 W.	·H+2⫶C+·K	100.44	1 Water	9	+ 1 Bicarbonate	91.44
Chlorate,	⫶⫶Cl+·K	122.7	1 Chloric Acid	75.5	+ 1 Potassa	47.2
Perchlorate,	⫶⫶⫶Cl+·K	138.7	1 Perchlo. Acid	91.5	+ 1 Potassa	47.2
Chromate,	⫶Cr·K	99.39	1 Chrom. Acid	52.19	+ 1 Potassa	47.2
Bichromate,	2⫶Cr+·K	151.58	2 Chrom. A.	104.38	+ 1 Potassa	47.2
Ferroprussiate, or Ferrocyanate. See Hydrocyanic Acid.						
Hydrate,	·H+·K	56.2	1 Water	9	+ 1 Potassa	47.2
Terhydrate,	3·H+·K	74.2	3 Water	27	+ 1 Potassa	47.2
Nitrate,	⫶⫶N·K	101.4	1 Nitric Acid	54.2	+ 1 Potassa	47.2
Oxalate,	⫶C²·K	83.44	1 Oxalic Acid	36.24	+ 1 Potassa	47.2
Sulphate,	⫶S·K	87.3	1 Sulph. Acid	40.1	+ 1 Potassa	47.2
Bisulphate,	2⫶S+·K	127.4	2 Sulph. Acid	80.2	+ 1 Potassa	47.2
Cr. 2 W.	2·H+2⫶S+K	145.4	2 Water	18	+ 1 Bisulphate	127.4
Tartrate,	T·K	113.68	1 Tartar. Acid	66.48	+ 1 Potassa	47.2
Bitartrate,	2T+·K	180.16	2 Tartar. Acid	132.96	+ 1 Potassa	47.2
Cr. 2 W.	2·H+2T+·K	198.16	2 Water	18	+ 1 Bitartrate	180.16

	Symbol.	Atomic Weight.	Composition.			
SODIUM,	Na	23.5				
Chloride,	ClNa	59	1 Chlorine	35.5	+ 1 Sodium	23.5
Iodide,	INa	150	1 Iodine	126.5	+ 1 Sodium	23.5
Bromide,	BrNa	101.9	1 Bromine	78.4	+ 1 Sodium	23.5
Fluoride,	FNa	42.2	1 Fluorine	18.7	+ 1 Sodium	23.5
Sulphuret,	SNa	39.6	1 Sulphur	16.1	+ 1 Sodium	23.5
Oxide (Soda)	·Na	31.5	1 Oxygen	8	+ 1 Sodium	23.5
Peroxide,	:Na²	71	3 Oxygen	24	+ 2 Sodium	47
SODA, salts of						
Acetate,	A·Na	82.98	1 Acetic Acid	51.48	+ 1 Soda	31.5
Biborate,	2:B+·Na	101.5	2 Boracic Acid	70	+ 1 Soda	31.5
Cr.10W.(borax)	10·H+2:B+·Na	191.5	10 Water	90	+ 1 Biborate	101.5
Carbonate,	:C·Na	53.62	1 Carbon. Acid	22.12	+ 1 Soda	31.5
Cr. 10 W.	10·H+:C·Na	143.62	10 Water	90	+ 1 Carbonate	53.62
Sesquicarbonate,	3:C+2·Na	129.36	3 Carbon. Acid	66.36	+ 2 Soda	63
Cr. 4. W.	4·H+3:C+2·Na	165.36	4 Water	36	+ 1 Sesquicarbo.	129.36
Chlorate,	::Cl·Na	107.0	1 Chloric Acid	75.5	+ 1 Soda	31.5
Hydrate,	·H·Na	40.5	1 Water	9	+ 1 Soda	31.5
Iodate,	::I·Na	198.0	1 Iodic Acid	166.5	+ 1 Soda	31.5
Nitrate,	::N·Na	85.7	1 Nitric Acid	54.2	+ 1 Soda	31.5
Oxalate,	:C²·Na	67.74	1 Oxalic Acid	36.24	+ 1 Soda	31.5
Sulphate,	:S·Na	71.6	1 Sulph. Acid	40.1	+ 1 Soda	31.5
Cr. 10 W.	10·H+:S·Na	161.6	10 Water	90	+ 1 Sulphate	71.6
Tartrate,	T·Na	97.98	1 Tartar. Acid	66.48	+ 1 Soda	31.5
and POTASSA, Tartrate of, Cr. 8 W.			1 Tar. of Pot.	113.68	+ 1 Tar. of Soda	97.98
	8·H+T·K+T·N	283.66			+ 8 Water	72
LITHIUM,	L	10				
Chloride,	ClL	45.5	1 Chlorine	35.5	+ 1 Lithium	10
Fluoride,	FL	28.7	1 Fluorine	18.7	+ 1 Lithium	10
Oxide,	·L	18	1 Oxygen	8	+ 1 Lithium	10
LITHIA, Salts of,						
Carbonate,	:C·L	40.12	1 Carbo. Acid	22.12	+ 1 Lithia	18
Nitrate,	::N·L	72.2	1 Nitric Acid	54.2	+ 1 Lithia	18
Sulphate,	:S·L	58.1	1 Sulph. Acid.	40.1	+ 1 Lithia	18
AMMONIA,	NH³	17.2	1 Nitrogen	14.2	+ 3 Hydrogen	3
Acetate,	A+NH³	68.68	1 Acetic Acid	51.48	+ 1 Ammonia	17.2
Cr. 7 W.	7·H+A+NH³	131.68	7 Water	63	+ 1 Acetate	68.68

	Symbol.	Atomic Weight.	Composition.	
Benzoate, . .	$B+NH^3$	131.88	**1** Benzo. Acid 114.68 + **1** Ammonia	17.2
Cr. 1 W. .•	$\cdot H+B+NH^3$	140.88	**1** Water 9 + **1** Benzoate	131.88
Carbonate, `.` .	$:C+NH^3$	39.32	**1** Carbo. Acid 22.12 + **1** Ammonia	17.2
Bicarbonate, .	$2:C+NH^3$	61.44	**2** Carbo. Acid 44.24 + **1** Ammonia	17.2
Cr. 2 W. .	$2 \cdot H+2:C+NH^3$	79.44	**2** Water 18 + **1** Bicarbonate	61.44
Sesquicarbonate,	$3:C+2(NH^3)$	100.76	**3** Carb. Acid 66.36 + **2** Ammonia	34.4
Cr. 2 W.	$2 \cdot H+3:C+2(NH^3)$	118.76	**2** Water 18 + **1** Sesquicarbo.	100.76
Hydriodate, . .	$HI+NH^3$	144.7	**1** HydriodicA.127.5 + **1** Ammonia	17.2
Iodate, . . .	$::I+NH^3$	183.7	**1** Iodic Acid 166.5 + **1** Ammonia	17.2
Hydrochlorate, .	$HCl+NH^3$	53.7	**1** Hydrochl. A. 36.5 + **1** Ammonia	17.2
Nitrate, . .	$::N+NH^3$	71.4	**1** Nitric Acid 54.2 + **1** Ammonia	17.2
Cr. 1 W. .	$\cdot H+::N+NH^3$	80.4	**1** Water 9 + **1** Nitrate	71.4
Oxalate, . .	$:C^2+NH^3$	53.44	**1** Oxalic Acid 36.24 + **1** Ammonia	17.2
Cr. 2 W. .	$2 \cdot H+:C^2+NH^3$	71.44	**2** Water 18 + **1** Oxalate	53.44
Binoxalate, .	$2(:C^2)+NH^3$	89.68	**2** Oxalic Acid 72.48 + **1** Ammonia	17.2
Cr. 8 W.	$8 \cdot H+2(:C^2)+NH^3$	161.68	**8** Water 72 + **1** Binoxalate	89.68
Succinate, . .	$S+NH^3$	67.68	**1** Succinic Acid50.48 + **1** Ammonia	17.2
Cr.				
Sulphate, . .	$:S+NH^3$	57.3	**1** Sulphuric A. 40.1 + **1** Ammonia	17.2
Cr. 2 W. .	$2 \cdot H+:S+NH^3$	75.3	**2** Water 18 + **1** Sulphate	57.3
Sulphite, . .	$:S+NH^3$	49.3	**1** SulphurousA.32.1 + **1** Ammonia	17.2

ORDER II.—TERRIGENOUS METALS.

	Symbol.	Atomic Weight.	Composition.	
CALCIUM, .	Ça	20.5		
Chloride, . .	ClCa	56	**1** Chlorine 35.5 + **1** Calcium	20.5
Cr. 6 W. .	$6 \cdot H+ClCa$	110	**6** Water 54 + **1** Chloride	56
Iodide, . .	ICa	147	**1** Iodine 126.5 + **1** Calcium	20.5
Bromide, . .	BrCa	98.9	**1** Bromine 78.4 + **1** Calcium	20.5
Fluoride, . .	FCa	39.2	**1** Fluorine 18.7 + **1** Calcium	20.5
Sulphuret . .	SCa	36.6	**1** Sulphur 16.1 + **1** Calcium	20.5
Phosphuret, . .	PCa	36.2	**1** Phosphorus 15.7 + **1** Calcium	20.5
Oxide (Lime), . .	$\cdot Ca$	28.5	**1** Oxygen 8 + **1** Calcium	20.5
Binoxide, . .	$:Ca$	36.5	**2** Oxygen 16 + **1** Calcium	20.5
Salts of Lime.				
Acetate, .	$A+\cdot Ca$	79.98	**1** Acetic Acid 51.48 + **1** Lime	28.5
Carbonate, .	$:C+\cdot Ca$	50.62	**1** Carbo. Acid 22.12 + **1** Lime	28.5
Chlorate, .	$::Cl+\cdot Ca$	104	**1** Chloric Acid 75.5 + **1** Lime	28.5

	Symbol.	Atomic Weight.	Composition.			
Chloride, . . .	Cl·Ca	54	**1** Chlorine	35.5	+ **1** Lime	28.5
Citrate, . . .	C+·Ca	86.98	**1** Citric Acid	58.48	+ **1** Lime	28.5
Hydrate, . . .	·H+·Ca	37.5	**1** Water	9	+ **1** Lime	28.5
Nitrate, . .	::N+·Ca	82.7	**1** Nitric Acid	54.2	+ **1** Lime	28.5
Oxalate, . . .	:C²+·Ca	64.74	**1** Oxalic Acid	36.24	+ **1** Lime	28.5
Dried at 100°,	2·H+:C²+·Ca	82.74	**2** Water	18	+ **1** Oxalate	64.74
Sulphate, . . .	:S+·Ca	68.6	**1** Sulph. Acid	40.1	+ **1** Lime	28.5.
Cr. 2 W. .	2·H+:S+·Ca	86.6	**2** Water	18 ·	+ **1** Sulphate	68.6
Tartrate, . . .	T+·Ca	94.98	**1** Tartaric Acid	66.48	+ **1** Lime	28.5
BARIUM, . . .	'Ba	68.6				
Chloride, . . .	ClBa	104.1	**1** Chlorine	35.5	+ **1** Barium	68.6
Cr. 2 W. .	2·H+ClBa	122.1 •	**2** Water	18	+ **1** Chloride	104.1
Iodide, ...	IBa	195.1	**1** Iodine	126.5	+ **1** Barium	68.6
Bromide, . . .	BrBa	147.0	**1** Bromine	78.4	+ **1** Barium	68.6
Fluoride, . . .	FBa	87.3	**1** Fluorine	18.7	+ **1** Barium	68.6
Sulphuret, . . .	SBa	84.7	**1** Sulphur	16.1	+ **1** Barium	68.6
Oxide (baryta), . . .	·Ba	76.6	**1** Oxygen	8	+ **1** Barium	68.6
Binoxide, . . .	:Ba	84.6	**2** Oxygen	16	+ **1** Barium	68.6
SALTS OF BARYTA,						
Acetate, ...	A·Ba	128.08	**1** Acetic Acid	51.48	+ **1** Baryta	76.6
Cr. 1 W. .	·H+A·Ba	137.08	**1** Water	9	+ **1** Acetate	128.08
Carbonate, . . .	:C·Ba	98.72	**1** Carbon. Acid	22.12	+ **1** Baryta	76.6
Chlorate, . . .	::Cl·Ba	152.1	**1** Chloric Acid	75.5	+ **1** Baryta	76.6
Chromate, . . .	:Cr·Ba	128.79	**1** Chrom. Acid	52.19	+ **1** Baryta	76.6
Hydrate, . . .	·H+·Ba	85.6	**1** Water	9	+ **1** Baryta	76.6
Iodate, ...	::I·Ba	243.1	**1** Iodic Acid	166.5	+ **1** Baryta	76.6
Nitrate, ...	::N·Ba	130.8	**1** Nitric Acid	54.2	+ **1** Baryta	76.6
Oxalate, . . .	:C²+·Ba	112.84	**1** Oxalic Acid	36.24	+ **1** Baryta	76.6
Cr. 1 W. .	·H+:C²+·Ba	121.84	**1** Water .	9	+ **1** Oxalic Acid	36.24
					+ **1** Baryta	76.6
Binoxalate, .	2:C²+·Ba	149.08	**2** Oxalic Acid	72.48	+ **1** Baryta	76.6
Cr. 2 W. .	2·H+2:C²+·Ba	167.08	**2** Oxalic Acid	72.48	+ **2** Water	18
					+ **1** Baryta	76.6
Sulphate, . . .	:S+·Ba	116.7	**1** Sulph. Acid	40.1	+ **1** Baryta	76.6
STRONTIUM, . . .	Sr	43.8				
Chloride, ...	ClSr	79.3	**1** Chlorine	35.5	+ **1** Strontium	43.8
Cr. 1 W. . .	·H+ClSr	88.3	**1** Water	9	+ **1** Chloride	79.3
Iodide, ...	ISr	170.3	**1** Iodine	126.5	+ **1** Strontium	43.8

	Symbol.	Atomic Weight.	Composition.			
Sulphuret, . . .	SSr	59.9	1 Sulphur	16.1 + 1 Strontium	43.8	
Oxide (Strontia), . .	·Sr	51.8	1 Oxygen	8 + 1 Strontium	43.8	
Binoxide, · . .	:Sr	59.8	2 Oxygen	16 + 1 Strontium	43.8	
STRONTIA, SALTS OF,						
Acetate, ...	A·Sr	103.28	1 Acetic Acid	51.48 + 1 Strontia	51.8	
Carbonate, . . .	:C·Sr	73.92	1 Carbo. Acid	22.12 + 1 Strontia	51.8	
Hydrate, . .	·H+·Sr	60.8	1 Water	9 + 1 Strontia	51.8	
Nitrate, . . .	::N+·Sr	106	1 Nitric Acid	54.2 + 1 Strontia	51.8	
Cr. 5 W. .	5·H+::N:Sr	151	5 Water	45 + 1 Nitrate	106	
Sulphate, . ,. .	:S+·Sr	91.9	1 Sulph. Acid	40.1 + 1 Strontia	51.8	
MAGNESIUM, . .	Mg	12.7				
Chloride, . . .	ClMg	48.2	1 Chlorine	35.5 + 1 Magnesium	12.7	
Cr. 6 W. . .	6·H+ClMg	102.2	6 Water	54 + 1 Chloride	48.2	
Iodide, ...	IMg	139.2	1 Iodine	126.5 + 1 Magnesium	12.7	
Bromide, . . .	BrMg	91.1	1 Bromine	78.4 + 1 Magnesium	12.7	
Fluoride, ...	FMg	31.4	1 Fluorine	18.7 + 1 Magnesium	12.7	
Oxide (Magnesia), .	·Mg	20.7	1 Oxygen	8 + 1 Magnesium	12.7	
MAGNESIA, SALTS OF,						
Acetate, . . .	A+·Mg	72.18	1 Acetic Acid	51.48 + 1 Magnesia	20.7	
CARBONATE, . .	:C+·Mg	42.82	1 Carbo. Acid	22.12 + 1 Magnesia	20.7	
Hydrate, . . .	·H+·Mg	29.7	1 Water	9 + 1 Magnesia	20.7	
Nitrate, . . .	::N+·Mg	74.9	1 Nitric Acid	54.2 + 1 Magnesia	20.7	
Cr. 6 W. .	6·H+::N+·Mg	128.9	6 Water	54 + 1 Nitrate	74.9	
Sulphate, . . .	:S+·Mg	60.8	1 Sulph. Acid	40.1 + 1 Magnesia	20.7	
Cr. 7 W. .	7·H+:S+·Mg	123.8	7 Water	63 + 1 Sulphate	60.8	
Tartrate, . . .	T+·Mg	87.18	1 Tartar. Acid	66.48 + 1 Magnesia	20.7	
Cr. 1 W. . .	·H+T·Mg	96.18	1 Water	9 + 1 Tartrate	87.18	
ALUMINUM, . .	Al	13.7				
Sesquichloride, . .	Cl³Al²	133.9	3 Chlorine	106.5 + 2 Aluminum	27.4	
Sesquisulphuret, · . .	S³Al²	·75.7	3 Sulphur	48.3 + 2 Aluminum	27.4	
Sesquioxide, (Alumina) .	· O³Al²	51.4	3 Oxygen	24 + 2 Aluminum	27.4	
ALUMINA, SALTS OF,						
Sulphate, . .	:S+:Al²	91.5	1 Sulph. Acid	40.1 + 1 Alumina	51.4	
And Potassa, sulphate of (alum),	:S·K+(3:S+:Al²) +24·H	475	1 Sulph. Pot. 87.3 + 1 Tersulph. of Alumina 171.7 + 24 Water		216	

ORDER III.—CALCIGENOUS METALS.

SECT. I.—METALS WHOSE OXIDES CANNOT BE REDUCED BY EXPOSURE TO HEAT ALONE.

	Symbol.	Atomic Weight.	Composition.				
IRON, ...	Fe	28					
Chloride, . . .	ClFe	63.5	**1** Chlorine	35.5	**+ 1** Iron	28	
Sesquichloride (Terdichl.),	Cl^{3}Fe^2	162.5	**3** Chlorine	106.5	**+ 2** Iron	56	
Iodide, ...	IFe	154.5	**1** Iodine	126.5	**+ 1** Iron	28	
Sesquiniodide (Terdiniod.),	I^{3}Fe^2	435.5	**3** Iodine	379.5	**+ 2** Iron	56	
Sulphuret, . . .	SFe	44.1	**1** Sulphur	16.1	**+ 1** Iron	28	
Bisulphuret, . . .	S^{2}Fe	60.2	**2** Sulphur	32.2	**+ 1** Iron	28	
Oxide, ...	·Fe	36	**1** Oxygen	8	**+ 1** Iron	28	
Sesquinoxide (Per or Terdin.),	:Fe^2	80	**3** Oxygen	24	**+ 2** Iron	56	
...... (Black oxide),	·:Fe^3	116	**4** Oxygen	32	**+ 3** Iron	84	
OXIDE OF IRON, SALTS OF,							
Carbonate . . .	:C+·Fe	58.12	**1** Carbo. Acid	22.12	**+ 1** Oxide of Iron	36	
Nitrate . . .	::N+·Fe	90.2	**1** Nitric Acid	54.2	**+ 1** Oxide of Iron	36	
Cr. 7 W. . .	·H+::N+·Fe	153.2	**7** Water	63	**+ 1** Nitrate	90.2	
Sulphate . . .	:S+·Fe	76.1	**1** Sulph. Acid	40.1	**+ 1** Oxide of Iron	36	
Cr. 7 W. . .	7·H+:S·Fe	139.1	**7** Water	63	**+ 1** Sulphate	76.1	
PEROXIDE OF IRON, SALTS OF,							
Terpersulphate, .	3:S+:Fe^2	160.3	**3** Sulph. Acid	120.3	**+ 1** Peroxide	80	
Dipersulphate, .	:S+2:Fe^2	120.1	**1** Sulph. Acid	40.1	**+ 2** Peroxide	160	
LEAD, ...	Pb	103.7					
Chloride, . . .	ClPb	139.2	**1** Chlorine	35.5	**+ 1** Lead	103.7	
Iodide, ...	IPb	230.2	**1** Iodine	126.5	**+ 1** Lead	103.7	
Sulphuret, . . .	SPb	119.8	**1** Sulphur	16.1	**+ 1** Lead	103.7	
Oxide, ...	·Pb	111.7	**1** Oxygen	8	**+ 1** Lead	103.7	
Dinoxide, . . .	·Pb^2	215.4	**1** Oxygen	8	**+ 2** Lead	207.4	
Quadrotrisoxide, . .	·:Pb^3	343.1	**4** Oxygen	32	**+ 3** Lead	311.1	
Binoxide (Peroxide), .	:Pb	119.7	**2** Oxygen	16	**+ 1** Lead	103.7	
OXIDE OF LEAD, SALTS OF,							
Acetate, . . .	A·Pb	163.18	**1** Acetic Acid	51.48	**+ 1** Ox. of Lead	111.7	
Cr. 3 W. . .	3·H+A·Pb	190.18	**3** Water	27	**+ 1** Acetate	163.1	
Ditacetate, . .	A+2·Pb	274.88	**1** Acetic Acid	51.48	**+ 2** Ox. of Lead	223.4	

	Symbol.	Atomic Weight.	Composition.
Carbonate,	:C+·Pb	133.82	1 Carbo. Acid 22.12 + 1 Oxide Lead 111.7
Chromate,	:Cr+·Pb	163.89	1 Chrom. Acid 52.19 + 1 Oxide Lead 111.7
Dichromate,	:Cr+2·Pb	275.59	1 Chrom. Acid 52.19 + 2 Oxide Lead 223.4
Iodate,	::I+·Pb	278.2	1 Iodic Acid 166.5 + 1 Oxide Lead 111.7
Molybdate,	:Mo+·Pb	183.6	1 Molyb. Acid 71.9 + 1 Oxide Lead 111.7
Nitrate,	::N+·Pb	165.9	1 Nitric Acid 54.2 + 1 Oxide Lead 111.7
Dinitrate,	::N+2·Pb	277.6	1 Nitric Acid 54.2 + 2 Oxide Lead 223.4
Oxalate,	:C²+·Pb	147.94	1 Oxalic Acid 36.24 + 1 Oxide Lead 111.7
Sulphate,	:S+·Pb	151.8	1 Sulphu. Acid 40.1 + 1 Oxide Lead 111.7
Tartrate,	T+·Pb	178.18	1 Tartar. Acid 66.48 + 1 Oxide Lead 111.7
COPPER,	Cu	31.7	
Dichloride,	Cl+2Cu	98.9	1 Chlorine 35.5 + 2 Copper 63.4
Chloride,	Cl+Cu	67.2	1 Chlorine 35.5 + 1 Copper 31.7
Diniodide,	I+2Cu	189.9	1 Iodine 126.5 + 2 Copper 63.4
Disulphuret,	S+2Cu	79.5	1 Sulphur 16.1 + 2 Copper 63.4
Sulphuret,	S+Cu	47.8	1 Sulphur 16.1 + 1 Copper 31.7
Dinoxide,	·Cu²	71.4	1 Oxygen 8 + 2 Copper 63.4
Oxide,	·Cu	39.7	1 Oxygen 8 + 1 Copper 31.7
OXIDE OF COPPER, SALTS OF,			
Ditacetate,	A+2·Cu	130.88	1 Acetic Acid 51.48 + 2 Oxy. Copper 79.4
Cr. 6 W.	6·H+(A+2·Cu)	184.88	6 Water 54 + 1 Diacetate 130.88
Acetate,	A+·Cu	91.18	1 Acetic Acid 51.48 + 1 Oxy. Copper 39.7
Cr. 1 W.	·H+(A+·Cu)	100.18	1 Water 9 + 1 Acetate 91.18
Sesquiacetate?	2A+3·Cu	222.06	2 Acetic Acid 102.96 + 3 Oxy. Copper 119.1
Cr. 6 W.	6·H+(2A+3·Cu)	276.06	6 Water 54 + 1 Sesquiacetate 222.06
Tritacetate,	A+3·Cu	170.58	1 Acetic Acid 51.48 + 3 Oxy. Copper 119.1
Cr. 2 W.	2·H+(A+3·Cu)	188.58	2 Water 18 + 1 Tritacetate 170.58
Dicarbonate,	:C+2·Cu	101.52	1 Carbo. Acid 22.12 + 2 Oxy. Copper 79.4
Hydrated,	·H+(:C+2·Cu)	110.52	1 Water 9 + 1 Dicarbonate 101.52
Nitrate,	::N+·Cu	93.9	1 Nitric Acid 54.2 + 1 Oxy. Copper 39.7
Sulphate,	:S+·Cu	79.8	1 Sulph. Acid 40.1 + 1 Oxy. Copper 39.7
Cr. 5 W.	5·H+(:S+·Cu)	124.8	5 Water 45 + 1 Sulphate 79.8
ZINC,	Z	32.3	
Chloride,	ClZ	67.8	1 Chlorine 35.5 + 1 Zinc 32.3
Iodide,	IZ	158.8	1 Iodine 126.5 + 1 Zinc 32.3
Sulphuret,	SZ	48.4	1 Sulphur 16.1 + 1 Zinc 32.3
Oxide,	·Z	40.3	1 Oxygen 8 + 1 Zinc 32.3

	Symbol.	Weight.	Composition.
Salts of Oxide of Zinc.			
Acetate,	$A+\cdot Z$	91.78	**1** Acetic Acid 51.48 + **1** Oxide of Zinc 40.3
Cr. 7 W.	$7\cdot H+(A+\cdot Z)$	154.78	**7** Water 63 + **1** Acetate 91.78
Carbonate,	$:C+\cdot Z$	62.42	**1** Carbo. Acid 22.12 + **1** Oxide of Zinc 40.3
Nitrate,	$::N+\cdot Z$	94.5	**1** Nitric Acid 54.2 + **1** Oxide of Zinc 40.3
Cr. 6 W.	$6\cdot H+(::N\cdot Z)$	148.5	**6** Water 54 + **1** Nitrate 94.5
Sulphate,	$:S+\cdot Z$	80.4	**1** Sulph. Acid 40.1 + **1** Oxide of Zinc 40.3
Cr. 7 W.	$7\cdot H+(:S+\cdot Z)$	143.4	**7** Water 63 + **1** Sulphate 80.4
Tartrate,	$T+\cdot Z$	106.78	**1** Tartar. Acid 66.48 + **1** Oxide of Zinc 40.3
ANTIMONY,	Sb	64.6	
Sesquichloride,	Cl^3+Sb^2	235.7	**3** Chlorine 106.5 + **2** Antimony 129.2
Sesquisulphuret,	S^3+Sb^2	177.5	**3** Sulphur 48.3 + **2** Antimony 129.2
Sesquioxide,	$:Sb^2$	153.2	**3** Oxygen 24 + **2** Antimony 129.2
Antimonious Acid,	$\cdot:Sb^2$	161.2	**4** Oxygen 32 + **2** Antimony 129.2
Antimonic Acid,	$::Sb^2$	169.2	**5** Oxygen 40 + **2** Antimony 129.2

Sesquioxide and Potassa, Tartrate of,

$$2T+\cdot K+:Sb^2+3.H \quad 360.36$$

$$\left\{\begin{array}{l} \textbf{2}\text{ Tartaric Acid } 132.96 \\ \textbf{1}\text{ Potassa } 47.2 \\ \textbf{1}\text{ Sesquiox.Ant. } 153.2 \\ \textbf{3}\text{ Water } 27 \\ \hline 360.36 \end{array}\right.$$

	Symbol.	Weight.	Composition.
TIN,	Sn	58.9	
Chloride,	ClSn	94.4	**1** Chlorine 35.5 + **1** Tin 58.9
Bichloride,	Cl^2Sn	129.9	**2** Chlorine 71 + **1** Tin 58.9
Iodide,	ISn	185.4	**1** Iodine 126.5 + **1** Tin 58.9
Sulphuret,	SSn	75	**1** Sulphur 16.1 + **1** Tin 58.9
Bisulphuret,	S^2Sn	91.1	**2** Sulphur 32.2 + **1** Tin 58.9
Sesquisulphuret,	S^3Sn^2	166.1	**3** Sulphur 48.3 + **2** Tin 117.8
Oxide,	$\cdot Sn$	66.9	**1** Oxygen 8 + **1** Tin 58.9
Sesquioxide,	$:Sn^2$	141.8	**3** Oxygen 24 + **2** Tin 117.8
Binoxide,	$:Sn$	74.9	**2** Oxygen 16 + **1** Tin 58.9
BISMUTH,	Bi	71.5	
Chloride,	ClBi	107	**1** Chlorine 35.5 + **1** Bismuth 71.5
Sulphuret,	SBi	87.6	**1** Sulphur 16.1 + **1** Bismuth 71.5
Oxide,	$\cdot Bi$	79.5	**1** Oxygen 8 + **1** Bismuth 71.5
Sesquioxide,	$:Bi^2$	167	**3** Oxygen 24 + **2** Bismuth 143
Oxide of Bismuth, Salts of,			
Carbonate,	$:C+\cdot Bi$	101.62	**1** Carbo. Acid 22.12 + **1** Ox. Bismuth 79.5
Trisnitrate,	$::N+3\cdot Bi$	292.7	**1** Nitric Acid 54.2 + **3** Ox. Bismuth 238.5

	Symbol.	Atomic Weight.	Composition.			
Nitrate, . . .	∷N+·Bi	133.7	**1** Nitric Acid	54.2	+**1** Ox. Bismuth	79.5
Cr. 3 W. .	3·H+(∷N+·Bi)	160.7	**3** Water	27	+**1** Nitrate	133.7
Sulphate, . . .	∶S+·Bi	119.6	**1** Sulph. Acid	40.1	+**1** Ox. Bismuth	79.5
Tartrate, . . .	T+·Bi	145.98	**1** Tartar. Acid	66.48	+**1** Ox. Bismuth	79.5
MANGANESE, . .	Mn	27.7				
Chloride, . . .	ClMn	63.2	**1** Chlorine	35.5	+**1** Manganese	27.7
Perchloride, . .	Cl⁷Mn²	303.9	**7** Chlorine	248.5	+**2** Manganese	55.4
Sulphuret, . .	SMn	43.8	**1** Sulphur	16.1	+**1** Manganese	27.7
Oxide, . . .	·Mn	35.7	**1** Oxygen	8	+**1** Manganese	27.7
Sesquioxide. . .	∶Mn²	79.4	**3** Oxygen	24	+**2** Manganese	55.4
Red Oxide, . .	·∶Mn³	115.1	**4** Oxygen	32	+**3** Manganese	83.1
Varvicite, . . .	·∶∶Mn⁴	166.8	**7** Oxygen	56	+**4** Manganese	110.8
Binoxide, . . .	∶Mn	43.7	**2** Oxygen	16	+**1** Manganese	27.7
Manganeseous Acid, .	∶Mn	51.7	**3** Oxygen	24	+**1** Manganese	27.7
Manganesic Acid, .	·∶∶Mn²	111.4	**7** Oxygen	56	+**2** Manganese	55.4
OXIDE OF MANGANESE, SALTS OF,						
Acetate, . .	A+·Mn	87.18	**1** Acetic Acid	51.48	+**1** Ox. Mang.	35.7
Cr. 4 W.	4·H+(A·Mn)	123.18	**4** Water	36	+**1** Acetate	87.18
Carbonate, . .	∶C+·Mn	57.82	**1** Carbonic A.	22.12	+**1** Ox. Mang.	35.7
Nitrate, . .	∷N+·Mn	89.9	**1** Nitric Acid	54.2	+**1** Ox. Mang.	35.7
Cr. 7 W.	7·H+(∷N·Mn)	152.9	**7** Water	63	+**1** Nitrate	89.9
Oxalate, . .	∶C²+·Mn	71.82	**1** Oxalic Acid	36.12	+**1** Ox. Mang.	35.7
Sulphate, . . .	∶S+·Mn	75.8	**1** Sulphuric A.	40.1	+**1** Ox. Mang.	35.7
CHROMIUM, . .	Cr	28.19				
Sesquichloride, . .	Cl³Cr²	162.88	**3** Chlorine	106.5	+**2** Chromium	56.38
Sesquisulphuret, . .	S³Cr²	104.68	**3** Sulphur	48.3	+**2** Chromium	56.38
Sesquioxide, . . .	∶Cr²	80.38	**3** Oxygen	24	+**2** Chromium	56.38
Chromic Acid, . .	∶Cr	52.19	**3** Oxygen	24	+**1** Chromium	28.19
COBALT, . . .	Co	29.5				
Chloride, . . .	ClCo	65	**1** Chlorine	35.5	+**1** Cobalt	29.5
Sulphuret, . . .	SCo	45.6	**1** Sulphur	16.1	+**1** Cobalt	29.5
Oxide, ...	·Co	37.5	**1** Oxygen	8	+**1** Cobalt	29.5
Sesquioxide, . . .	∶Co²	83	**3** Oxygen	24	+**2** Cobalt	59
OXIDE OF COBALT, SALTS OF,						
Carbonate, , . .	∶C+·Co	59.62	**1** Carbonic A.	22.12	+**1** Ox. Cobalt	37.5
Nitrate, . . .	∷N+·Co	91.7	**1** Nitric Acid	54.2	+**1** Ox. Cobalt	37.5
Cr. 6 W.	6·H+(∷N·Co)	145.7	**6** Water	54	+**1** Nitrate	91.7
Sulphate, . . .	∶S+·Co	77.6	**1** Sulphuric A.	40.1	+**1** Ox. Cobalt	37.5

	Symbol.	Atomic Weight.	Composition			
ARSENIC, . . .	As	37.7				
Chloride, . . .	ClAs	73.2	1 Chlorine	35.5	+ 1 Arsenic	37.7
Sesquichloride, . .	Cl³As²	181.9	3 Chlorine	106.5	+ 2 Arsenic	75.4
Sulphuret, . . .	SAs	53.8	1 Sulphur	16.1	+ 1 Arsenic	37.7
Sesquisulphuret, . .	S³As²	123.37	3 Sulphur	48.3	+ 2 Arsenic	75.4
Persulphuret, . . .	S⁵As²	155.9	5 Sulphur	80.5	+ 2 Arsenic	75.4
Hydruret, . . .	HAs	38.7	1 Hydrogen	1	+ 1 Arsenic	37.7
Sesquihydruret, . .	H³As²	78.4	3 Hydrogen	3	+ 2 Arsenic	75.4
Arsenious Acid, . .	3As²	99.4	3 Oxygen	24	+ 2 Arsenic	75.4
Arsenic Acid, . .	O⁵As²	115.4	5 Oxygen	40	+ 2 Arsenic	75.4
NICKEL, . . .	Ni	29.5				
Chloride, . . .	ClNi	65	1 Chlorine	35.5	+ 1 Nickel	29.5
Disulphuret, . . .	SNi²	75.1	1 Sulphur	16.1	+ 2 Nickel	59
Sulphuret, . . .	SNi	45.6	1 Sulphur	16.1	+ 1 Nickel	29.5
Oxide, ...	·Ni	37.5	1 Oxygen	8	+ 1 Nickel	29.5
Sesquioxide, . . .	3Ni²	83	3 Oxygen	24	+ 2 Nickel	59
SALTS OF OXIDE OF NICKEL.						
Carbonate, . .	3C+·Ni	59.62	1 Carbonic A.	22.12	+ 1 Ox. Nickel	37.5
Nitrate, . .	::N+·Ni	91.7	1 Nitric Acid	54.2	+ 1 Ox. Nickel	37.5
Sulphate, . .	3S+·Ni	77.6	1 Sulphuric A.	40.1	+ 1 Ox. Nickel	37.5
Cr. 7 W.	7·H+(3S+·Ni)	140.6	7 Water	63	+ 1 Sulphate	77.6
CADMIUM, . .	Cd	55.8				
Chloride, . . .	ClCd	91.3	1 Chlorine	35.5	+ 1 Cadmium	55.8
Iodide, . . .	ICd	182.3	1 Iodine	126.5	+ 1 Cadmium	55.8
Sulphuret, . . .	SCd	71.9	1 Sulphur	16.1	+ 1 Cadmium	55.8
Oxide, ...	·Cd	63.8	1 Oxygen	8	+ 1 Cadmium	55.8
SALTS OF OXIDE OF CADMIUM.						
Carbonate, . .	3C+·Cd	85.92	1 Carbonic A.	22.12	+ 1 Ox. Cadmium	63.8
Nitrate, . . .	::N+·Cd	118	1 Nitric Acid	54.2	+ 1 Ox. Cadmium	63.8
Cr. 4 W. .	4·H+(::N+·Cd)	154	4 Water	36	+ 1 Nitrate	118
Sulphate, . . .	3S+·Cd	103.28	1 Sulphuric A.	40.1	+ 1 Ox. Cadmium	63.18
Cr. 4 W. .	4·H+(3S+·Cd)	139.28	4 Water	36	+ 1 Sulphate	103.28
MOLYBDENUM, . .	Mo	47.9				
Chloride, . . .	ClMo	83.4	1 Chlorine	35.5	+ 1 Molybdenum	47.9
Bichloride, . . .	Cl²Mo	118.9	2 Chlorine	71	+ 1 Molybdenum	47.9
Bisulphuret, . . .	S²Mo	80.1	2 Sulphur	32.2	+ 1 Molybdenum	47.9
Tersulphuret, . .	S³Mo	96.2	3 Sulphur	48.3	+ 1 Molybdenum	47.9
Oxide, ...	·Mo	55.9	1 Oxygen	8	+ 1 Molybdenum	47.9

	Symbol.	Atomic Weight.	Composition.				
Binoxide, . . .	:Mo	63.9	**2** Oxygen	16	**+ 1** Molybdenum	47.9	
Molybdic Acid, . .	:Mo	71.9	**3** Oxygen	24	**+ 1** Molybdenum	47.9	
TUNGSTEN, (Wolfram)'	W.	94.8					
Bichloride, . . .	Cl²W	165.8	**2** Chlorine	71	**+ 1** Tungsten	94.8	
Bisulphuret, . . .	S²W	127.	**2** Sulphur	32.2	**+ 1** Tungsten	94.8	
Binoxide, . . .	:W	110.8	**2** Oxygen	16	**+ 1** Tungsten	94.8	
Sesquioxide, . . .	:W²	213.6	**3** Oxygen	24	**+ 2** Tungsten	189.6	
Tungstic Acid, . . .	:W	118.8	**3** Oxygen	24	**+ 1** Tungsten	94.8	
VANADIUM, . .	V	68.5					
Bichloride, . . .	Cl²V	139.5	**2** Chlorine	71	**+ 1** Vanadium	68.5	
Terchloride, . . .	Cl³V	175	**3** Chlorine	106.5	**+ 1** Vanadium	68.5	
Bisulphuret, . . .	S²V	100.7	**2** Sulphur	32.2	**+ 1** Vanadium	68.5	
Tersulphuret, . . .	S³V	116.8	**3** Sulphur	48.3	**+ 1** Vanadium	68.5	
Oxide, ...	·V	76.5	**1** Oxygen	8	**+ 1** Vanadium	68.5	
Binoxide, . . .	:V	84.5	**2** Oxygen	16	**+ 1** Vanadium	68.5	
Vanadic Acid, . . .	:V	92.5	**3** Oxygen	24	**+ 1** Vanadium	68.5	
URANIUM, . . .	U	217.2					
Chloride, . . .	ClU	252.7	**1** Chlorine	35.5	**+ 1** Uranium	217.2	
Sesquichloride, . .	Cl³U²	540.9	**3** Chlorine	106.5	**+ 2** Uranium	434.4	
Oxide, ...	·U	225.2	**1** Oxygen	8	**+ 1** Uranium	217.2	
Sesquioxide, . . .	:U²	458.4	**3** Oxygen	24	**+ 2** Uranium	434.4	
TITANIUM, . .	Ti	23.5					
Bichloride, . . .	Cl²Ti	94.5	**2** Chlorine	71	**+ 1** Titanium	23.5	
Bisulphuret, . . .	S²Ti	55.7	**2** Sulphur	32.2	**+ 1** Titanium	23.5	
Oxide ?							
Titanic Acid, . . .	:Ti	39.5	**2** Oxygen	16	**+ 1** Titanium	23.5	
TELLURIUM, . .	Te	64.2					
Chloride, . . .	ClTe	99.7	**1** Chlorine	35.5	**+ 1** Tellurium	64.2	
Bichloride, . . .	Cl²Te	135.2	**2** Chlorine	71	**+ 1** Tellurium	64.2	
Bisulphuret, ...	S²Te	96.4	**2** Sulphur	32.2	**+ 1** Tellurium	64.2	
Hydrotelluric Acid, .	HTe	65.2	**1** Hydrogen	1	**+ 1** Tellurium	64.2	
Tellurous Acid, . .	:Te	80.2	**2** Oxygen	16	**+ 1** Tellurium	64.2	
Telluric Acid, . . .	:Te	88.2	**3** Oxygen	24	**+ 1** Tellurium	64.2	
CERIUM, . . .	Ce	46					
Chloride, . . .	ClCe	81.5	**1** Chlorine	35.5	**+ 1** Cerium	46	
Sesquichloride, . .	Cl³Ce²	198.5	**3** Chlorine	106.5	**+ 2** Cerium	92	
Sulphuret, . . .	SCe	62.1	**1** Sulphur	16.1	**+ 1** Cerium	46	
Oxide, ...	·Ce	54	**1** Oxygen	8	**+ 1** Cerium	46	

	Symbol.	Atomic Weight.			Composition.		
Sesquioxide, . . .	:Ce²	116	**3** Oxygen	24	+ **2** Cerium	92	
COLUMBIUM, . .	Ta	184.8					
Terchloride, . .	Cl³Ta	291.3	**3** Chlorine	106.5	+ **1** Columbium	184.8	
Binoxide, . . .	:Ta	200.8	**2** Oxygen	16	+ **1** Columbium	184.8	
Columbic Acid, . .	?Ta	208.8	**3** Oxygen	24	+ **1** Columbium	184.8	

Sect. II.—Metals whose Oxides can be reduced by exposure to Heat alone.

	Symbol.	Atomic Weight.			Composition.		
MERCURY, . .	Hg	203					
Chloride, . . .	ClHg	238.5	**1** Chlorine	35.5	+ **1** Mercury	203	
Bichloride, . .	Cl²Hg	274	**2** Chlorine	71	+ **1** Mercury	203	
Iodide, ...	IHg	329.5	**1** Iodine	126.5	+ **1** Mercury	203	
Sesquiniodide, . .	I³Hg²	785.5	**3** Iodine	379.5	+ **2** Mercury	406	
Biniodide, . . .	I²Hg	456	**2** Iodine	253	+ **1** Mercury	203	
Sulphuret, . . .	SHg	219.1	**1** Sulphur	16.1	+ **1** Mercury	203	
Bisulphuret, . .	S²Hg	235.2	**2** Sulphur	32.2	+ **1** Mercury	203	
Oxide, ...	·Hg	211	**1** Oxygen	8	+ **1** Mercury	203	
Binoxide, . . .	:Hg	219	**2** Oxygen	16	+ **1** Mercury	203	
OXIDE OF MERCURY, SALTS OF,							
Sulphate, . . .	:S·Hg	251.1	**1** Sulph. Acid	40.1	+ **1** Oxide	211	
Nitrate, . . .	::N·Hg	265.2	**1** Nitric Acid	54.2	+ **1** Oxide	211	
Binaqueous, .	2·H+::N·Hg	283.2	**2** Water	18	+ **1** Nitric Acid	54.2	⎫
					+ **1** Oxide	211	⎭
BINOXIDE OF MERCURY, Salts of,							
Bisulphate of Binoxide,	2:S+:Hg	299.2	**2** Sulph. Acid	80.2	+ **1** Binoxide	219	
Nitrate of Binoxide,	::N+:Hg	273.2	**1** Nitric Acid	54.2	+ **1** Binoxide	219	
Binitrate of Binoxide,	2::N+:Hg	327.4	**2** Nitric Acid	108.4	+ **1** Binoxide	219	
Dinitrate, . .	::N+2:Hg	492.2	**1** Nitric Acid	54.2	+ **2** Binoxide	438	
SILVER, . .	Ag	108.3					
Chloride, . . .	ClAg	143.8	**1** Chlorine	35.5	+ **1** Silver	108.3	
Iodide, . . .	IAg	234.8	**1** Iodine	126.5	+ **1** Silver	108.3	
Sulphuret, . . .	SAg	124.4	**1** Sulphur	16.1	+ **1** Silver	108.3	
Oxide, ...	·Ag	116.3	**1** Oxygen	8	+ **1** Silver	108.3	
SALTS OF OXIDE OF SILVER,							
Acetate, . . .	A·Ag	167.78	**1** Acetic Acid	51.48	+ **1** Oxide Silver	116.3	
Carbonate, . .	:C+·Ag	138.42	**1** Carbo. Acid	22.12	+ **1** Oxide Silver	116.3	
Chlorate, . . .	::Cl+·Ag	191.8	**1** Chloric Acid	75.5	+ **1** Oxide Silver	116.3	

	Symbol	Atomic Weight.	Composition				
Nitrate,	:̈N+·Ag	170.5	**1** Nitric Acid	54.2	+ **1** Oxide Silver	116.3
Oxalate,	:̈C²+·Ag	152.54	**1** Oxalic Acid	36.24	+ **1** Oxide Silver	116.3
Sulphate,	:̈S+·Ag	156.4	**1** Sulph. Acid	40.1	+ **1** Oxide Silver	116.3
GOLD,	Au	200				
Chloride,	ClAu	235.5	**1** Chlorine	35.5	+ **1** Gold	200
Terchloride,	Cl³Au	306.5	**3** Chlorine	106.5	+ **1** Gold	200
Iodide,	IAu	326.5	**1** Iodine	126.5	+ **1** Gold	200
Teriodide,	I³Au	579.5	**3** Iodine	379.5	+ **1** Gold	200
Tersulphuret,	S³Au	248.3	**3** Sulphur	48.3	+ **1** Gold	200
Oxide,	·Au	208	**1** Oxygen	8	+ **1** Gold	200
Binoxide,	:Au	216	**2** Oxygen	16	+ **1** Gold	200
Teroxide,	⋮Au	224	**3** Oxygen	24	+ **1** Gold	200
PLATINUM,	Pt	98.84				
Chloride,	ClPt	134.34	**1** Chlorine	35.5	+ **1** Platinum	98.84
Bichloride,	Cl²Pt	169.84	**2** Chlorine	71	+ **1** Platinum	98.84
Iodide,	IPt	225.34	**1** Iodine	126.5	+ **1** Platinum	98.84
Biniodide,	I²Pt	351.84	**2** Iodine	253	+ **1** Platinum	98.84
Sulphuret,	SPt	114.94	**1** Sulphur	16.1	+ **1** Platinum	98.84
Bisulphuret,	S²Pt	131.04	**2** Sulphur	32.2	+ **1** Platinum	98.84
Oxide,	·Pt	106.84	**1** Oxygen	8	+ **1** Platinum	98.84
Binoxide,	:Pt	114.84	**2** Oxygen	16	+ **1** Platinum	98.84
PALLADIUM,	Pd	53.35				
Chloride,	ClPd	88.85	**1** Chlorine	35.5	+ **1** Palladium	53.35
Bichloride,	Cl²Pd	124.35	**2** Chlorine	71	+ **1** Palladium	53.35
Sulphuret,	SPd	69.45	**1** Sulphur	16.1	+ **1** Palladium	53.35
Oxide,	·Pd	61.35	**1** Oxygen	8	+ **1** Palladium	53.35
Binoxide,	:Pd	69.35	**2** Oxygen	16	+ **1** Palladium	53.35
RHODIUM,	R	52.2				
Chloride,	ClR	87.7	**1** Chlorine	35.5	+ **1** Rhodium	52.2
Sesquichloride,	Cl³R²	210.9	**3** Chlorine	106.5	+ **2** Rhodium	104.4
Oxide,	·R	60.2	**1** Oxygen	8	+ **1** Rhodium	52.2
Sesquioxide,	⋮R²	128.4	**3** Oxygen	24	+ **2** Rhodium	104.4

The equivalents of the phosphates are rather complicated, partly from the modifications of which phosphoric acid is susceptible as it passes into pyrophosphoric and metaphosphoric acids, and also from the nature of the combination it produces with salifiable bases. Farther, the specific terms applied to them will appear necessarily more complicated to those accustomed to the older nomenclature, where Professor Graham's important and ingenious views in respect to water are expressed in the new names, part of the water often performing the function of a salifiable base, while the rest may be combined in the usual manner as water of crystallization. The following symbols, &c. express the constitution of the more important phosphates ; the pyrophosphates and metaphosphates have not in general been so minutely examined as the phosphates. It will be seen from several of these, that phosphoric acid tends particularly to form compounds containing 3 atoms of base, and is hence said to be TRIBASIC; but pyrophosphoric acid forms bibasic compounds with the salifiable bases.

	Symbol.	Atomic Weight.	Con.
*Triphosphate of Soda and Basic Water,	$\{::P^2+2\cdot Na + \cdot H\}$	143.4	{**1** Phosphoric Acid 71.4+**2** Soda 63 + **1** Water 9}
Cr. Triphos. of Soda and Basic Water,	$\{24\cdot H+::P^2 +2\cdot Na+\cdot H\}$	359.4	{**24** Water of Cr.+**1** Phospho. Acid 71.4+ **2** Soda 63+**1** Water 9}
Cr. Triphos. of Soda and Basic Water,	$\{15\cdot H+::P^2 +2\cdot Na+\cdot H\}$	273.4	{**15** Water of Cr.+**1** Phospho. Acid 71.4+ **2** Soda 63+**1** Water 9}
Triphos.of Soda,Oxide Ammonium,and Basic Water,	$\{::P^2+\cdot Na+ \cdot NH^4+\cdot H\}$	138.1	{**1** Phosphoric Acid 71·4+**1** Soda 31.5+ **1** Oxide Ammo. 26.2+**1** Water 9}
† Cr. Triphosphate of Soda, Oxide Ammo. and Basic Water,	$\{8\cdot H+::P^2+ \cdot Na+\cdot NH^4 +\cdot H\}$	210.1	{**8** Water+Phosph. Acid 71.4+Soda 31.5+ **1** Oxide Ammonium 26.2+**1** Water 9}
‡ Teroctaphosphate of Lime,	$\{3::P^2+8\cdot Ca\}$	442.2	**3** Phosphoric Acid 214.2+ **8** Lime 228

* This salt, with water of crystallization, forms the Phosphate of Soda referred to in page 244.

† Crystallized Phosphate of Soda and Ammonia.   ‡ Phosphate from Bones.

EQUIVALENTS OF SOME OF THE MORE IMPORTANT COMPOUNDS FROM THE ANIMAL AND VEGETABLE KINGDOMS, AND OF COMPOUNDS PRODUCED BY THEIR DECOMPOSITION.

₊ *The Italic Capitals are used as Provisional Symbols.*

Acetic Acid,	.	(A) $3 \cdot H + C^4$ or $O^3 C^4 H^3$	51.48
Tartaric Acid,	. . .	(T) or $O^5 C^4 H^2$	66.48
Citric Acid,	. . .	(C) or $O^4 C^4 H^2$	58.48
Oxalic Acid,	. . . .	$(\vdots C^2)$ or $O^3 C^2$	36.24
Oxamide,	. . . .	$O^2 C_2 H^2 N$	44.44
Benzoic Acid,	. .	$(B$ or $\cdot Bz)$ or $O^3 C^{14} H^5$	114.68
Benzule,	. . . .	$(Bz) O^2 C^{14} H^5$	106.68
Gallic Acid,	. . . "	(G) or $O^5 C^7 H^3$	85.84
Succinic Acid,	. .	(S) or $O^3 C^4 H^2$	50.48
Cyanogen or Bicarburet of Nitrogen,	.	$C^2 N$	26.44
Hydrocyanic or Prussic Acid,	. .	$OHC^2 N$	27.44
Cyanic Acid,	. . . .	$\cdot C^2 N$	34.44
Ferroprussic Acid or Ferrohydro- cyanic Acid (Ferrocyanic Acid), }	$3(C^2 N) + 2H + Fe$	109.32
Hydrosulphocyanic Acid (Sulphocyanic Acid),	$HS^2 C^2 N$	59 64
Carbazotic Acid,	. . .	$O^{15} C^{15} N^3$	284.40
Morphia,	. . . .	$O^6 C^{34} H^{18} N$	288.28
Meconic Acid,	. . .	$O^7 C^7 H^2$	100.84
Metameconic Acid,	. . .	$O^{10} C^{12} H^4$	157.44
Pyromeconic Acid,	. . .	$O^5 C^{10} H^3$	104.2
Narcotine,	. . .	$O^{12} C^{40} H^{20} N$	375.
Codeia,	. . .	$O^5 C^{32} H^{19} N$	269.04
Narceia,	. . .	$O^{12} C^{38} H^{20} N$.	301.56
Thebaia,	. " . .	$O^3 C^{25} H^{14} N$	205.2
Meconin,	. . . .	$O^4 C^{10} H^8$	98.2
Quina,	. . . .	$O^2 C^{20} H^{12} N$	164.6
Cinchonia,	. , . .	$OC^{20} H^{12} N$	156.6
Strychnia,	. . .	$O^3 C^{30} H^{16} N$	237.8
Veratria,	. . .	$O^6 C^{34} H^{72} N$	292.28
Camphene,	. . . .	$C^{10} H^8$	69.2
Methylene,*	. . . .	HC ?	7.12 ?
Hydrate of Methylene (Pyroxilic Spirit),	OCH^2	16.12
Pyroacetic Spirit or Acetone,	. .	$OC^3 H^3$	29.36
Quadrocarbureted Hydrogen,	. .	$C^4 H^4$	28.48
Bicarbureted Hydrogen,	. . .	$C^2 H$	13.24

* The equivalents adopted here are doubled in some works, and the numbers adopted for several of the substances represented here must be considered provisional.

Alcohol, ...	OC^2H	**21.24**
Hydruret of Etherine (Ethule), .	$H+4HC$	**29.48**
Sulphuric Ether, $O+C^4H^5$, or $\cdot H+C^4H^4$, or OC^4H^5		**37.48**
Hyponitrous (Nitrous or Nitric Ether), $\frac{1}{2}N+OC^4H^5$		**75.68**
Oil of Wine, or Sulphate of Ether, $\frac{1}{2}S+OC^4H^5 \cdot$		**77.58**
Aldehyde, ...	OC^2H^2	**22.24**
Aldehydic Acid, . . .	$O^3C^4H^4$	**52.48**
Chloral, ...	$O^4C^9Cl^6$?	**300.08**
Acetal, ...	OC^8H^9	**65.96**
Mercaptan, or Hydruret of Mercaptum,	$H+S^2C^4H^5$	**62.68**
Zanthic Acid, . .	$2(SC)+OC^2H^3$	**99.88**
Arabine, . .	$O^{11}C^{12}H^{11}$	**172.44**
Dry Sugar, . .	$O^{10}C^{12}H^{10}$	**163.44**
Common Sugar, .	$O^{11}C^{12}H^{11}$	**172.44**
Diabetic Sugar, .	$\cdot O^{13}C^{12}H^{13}$	**190.44**
Starch Sugar, .	$O^{14}C^{12}H^{14}$	**199.44**
Tannin, or Tannic Acid,	$O^{12}C^{18}H^8$	**214.16**
Uric Acid, . .	$O^3C^6H^2N^2$	**91.12**
Urea, . .	$2(H^2OCN)$	**60.64**
Formic Acid, . .	O^3C^2H	**37.24**

II. LIGHT.

2371. The researches of science have shewn that the composition of the sunbeam is extremely complicated, and numerous and interesting as the various facts are which have been hitherto discovered, they still leave its history very incomplete, and abundant room for future investigation. The precise nature of heat and light is still unknown, and their relation to electricity, magnetism, and chemical action, is but imperfectly understood, though the connection between all these has in such numerous instances been proved to be so intimate, that the opinion that all the great phenomena of heat, light, electricity, magnetism, and attraction, including chemical action, may at some future period be proved to be dependent on one primary action, operating under extreme variety of circumstances, begins to be less improbable than it formerly appeared, while the progress of discovery in modern times has shewn how much is to be done, by studying their mutual relations.

2372. The question of the universal distribution of a thin and attenuated fluid usually called ETHER, is also necessarily involved in many of the speculations advocated, more especially at the present day, and this being thrown into vibrations or undulations, produces, it is supposed, according to the mode in which it is excited, the varied phenomena of heat and light.

2373. The sunbeam appears to consist of three very different kinds of rays, viz. Luminous, Calorific, and Chemical Rays, and of the two former there are different kinds, which has led to the supposition that the chemical rays may also be of a compound nature.

2374. Two opinions have been entertained as to the nature of light.

I. According to the *theory* of *Emission*, or the *corpuscular theory*, as it is often termed, light consists of a peculiar matter having particles infinitely small, so that, notwithstanding the velocity of their movements, 192,500 miles per second, they scarcely produce any marked impulse upon the body.

II. According to the *undulatory theory*, light is produced by vibrations or undulations in a peculiar ether, and this doctrine is supported more especially by the facts made known by Young, who shewed that two portions, or waves of light as they are termed, of the same force, destroy each other when they meet, interfering with or neutralizing one another, in the same manner as when two equal sounds are extinguished or terminate in silence, if the vibrations they produce be directed against each other.

2375. Whatever may be the interpretation adopted, the undulatory theory has in general been preferred, though the language currently employed is more in unison with the corpuscular theory. The extreme rapidity of these undulations, amounting to hundreds of millions in a single second, is one of the most curious and interesting facts that has hitherto been developed, and shews in a remarkable manner the sensibility of the eye, the various tints observed being dependent upon differences in the number of undulations, which are so rapid that it is easier to trace this in figures than to form any thing approaching to a precise idea of their frequency. The following tabular results by Herschel shew the relative rapidity of the different undulations.

Colours of the Spectrum.*	Number of Undulations in a Second.
Extreme Red, . . .	458,000000,000000
Red, . . .	477,000000,000000
Intermediate, . . .	495,000000,000000
Orange, . . .	506,000000,000000
Intermediate, . . .	517,000000,000000
Yellow, . . .	535,000000,000000
Intermediate, .	555,000000,000000
Green, ...	577,000000,000000
Intermediate, . . .	600,000000,000000
Blue, ...	622,000000,000000
Intermediate, . . .	644,000000,000000
Indigo, . . .	658,000000,000000
Intermediate, . . .	672,000000,000000
Violet, . . .	699,000000,000 00
Extreme Violet, . .	727,000000,000000

2376. Light appears to emanate from luminous objects in straight lines, diverging like the radii or spokes of a wheel, but on every side from the centre of emission. The accompanying figure illustrates the escape of light or heat from a luminous or warm body suspended in the air or in vacuo, omitting the action that is induced on a warm body by the contiguous air,† as heat is communicated to it by actual contact with the warm surface.

Fig. 239.
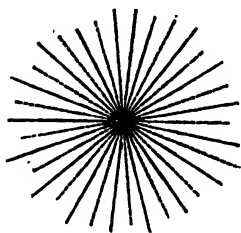
2377. Light falling upon any object must either be ABSORBED, TRANSMITTED, or REFLECTED ; or part may be affected in one of these ways, and other portions in a different manner. Bodies are *black* when they *absorb* light, *white* when it is *reflected, transparent* when it is transmitted, and of various colours when one portion is retained and another discharged. It may be considered doubtful, however, if in any case a portion of light falling on any substance is entirely absorbed, reflected, or transmitted, though much the greater portion may often be affected in one of these modes alone.

2378. A body may also present one tint when viewed by transmitted light, while its colour may appear very different if examined by reflected light.

2379. Light proceeds in straight lines as it passes through

Fig. 240.
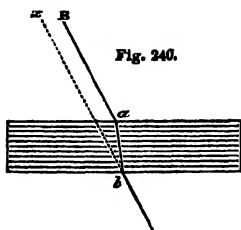
the same medium, but is altered or bent in its course when it passes from one kind of matter to another. This is termed the REFRACTION of Light. Thus a ray of light B*a* passing frôm the air to a piece of glass is bent in the direction *ab* as it enters the glass, and is again bent as it escapes from it, assuming the direction *bc*, parallel to the position it formerly held, as indicated by the dotted line *xb*.

2380. If the glass through which light is transmitted be convex, then the rays converge into a focus on the other side
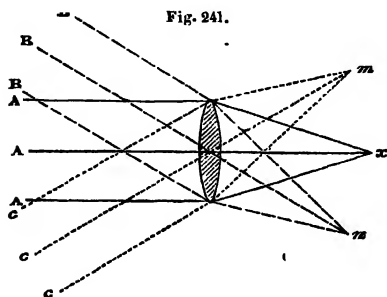
Fig. 241.

from that on which they impinge, the situation of which will vary according to the manner in which they fall upon the lens. Thus, if they arrive in the direction AAA, *x* will be the focus; if in the direction of BBB, the focus will be at *n*, but if in the direction CCC, the focus will be found at *m*.

2381. Again, while convex surfaces tend to concentrate the

Fig. 242.

rays of light in a focus, those that are concave have a totally opposite effect, dispersing the rays that pass through them in the manner shewn in the annexed figure, where the parallel rays that enter the glass are seen to diverge as they emerge from it.

2382. The refraction of light by water may be illustrated by
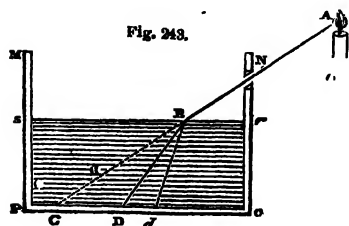
Fig. 243.

the familiar experiment represented in Fig. 243, a candle being placed so as to shine upon the bottom of a box, M N O P, through an aperture in the side. If C represent the point where the light falls when there is no water in the box, on filling it with this fluid to the level *rs*, the ray AB is

then bent at B, and appears at a different place, as at D; if a more powerfully refracting fluid were substituted for the water, the light might then be seen at *d*.

2383. Light is REFRACTED DOUBLY when it passes through some crystalline substances, as Iceland spar, one part being refracted in the usual manner, while another is said to undergo an extraordinary refraction. The primary is divided into two distinct parts. Hence such crystals present two images of any figure, of a circle or a line for example, traced on the surface upon which they may be placed, as in the diagram, where the ray is seen divided into two portions.
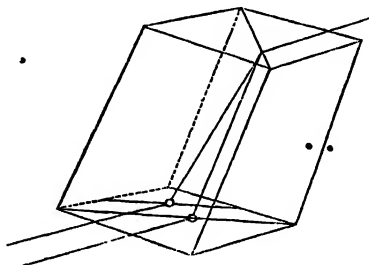
Fig. 244.

2384. Light is not only refracted when it passes through bodies; it is also affected when it moves near their edges when it is said to be INFLECTED or DIFFRACTED.

2385. Light is reflected at an angle equal to the angle at which it falls upon the reflecting surface, or, to use a familiar expression, the angle of incidence and the angle of reflection are equal. Thus, if a ray AB fall upon a reflecting surface CBD, the angle ABC formed by the incident ray and the plane upon which it falls is exactly equal to the angle FBD formed by the same plane and the reflected ray BF. The ray is never reflected in any other way, as in the direction of the lines *a*B, *b*B, or *c*B, Fig. 246.
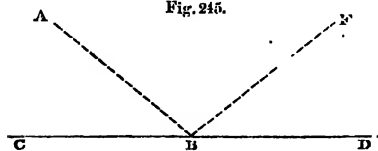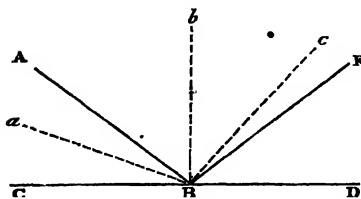
Fig. 245.

Fig. 246.

2386. If parallel rays of light fall upon a concave reflector,

they may be considered as impinging upon numerous small planes, which, from their different relative positions, cause the reflected rays to meet in a point or focus, each, however, form-

Fig. 247.
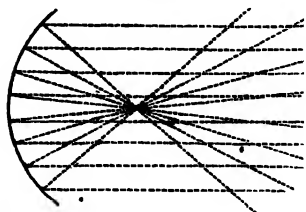
ing with that part of the reflector upon which it falls an angle of reflection equal to the angle of incidence ; and, if not absorbed by any substance placed at the focus, nor otherwise affected by meeting and impinging upon one another, they again diverge, proceeding in straight lines from that part from which they were reflected.

2387. But if parallel rays fall upon a convex reflecting surface, they are necessarily dispersed, as in Fig. 248, instead of being collected in a focus.
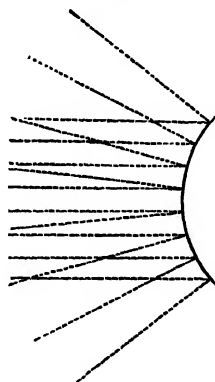
2388. POLARIZED LIGHT is the term applied to light when it has acquired peculiar properties in consequence of the circumstances under which it may have been reflected or refracted. Polarized light cannot be reflected from glass when it falls upon it at certain angles, while at others it is immediately reflected ; neither can it enter transparent media in the same manner as before, being transmitted

Fig. 248.

through them when it enters in one direction, while in others it has not the power of passing through them.

2389. Light is polarized when reflected from bright non-metallic surfaces at an angle of 56°.5 or 56°.45 ; and, though a portion may be polarized at a different angle, still, the more the angle of reflection differs from that mentioned, the less of the light is polarized. Malus, in 1810, discovered the polarization of light by reflection ; and Newton had previously considered that light became polarized in another way, viz. when subjected to the action of doubly refracting media. The power of polarized light to assist the eye in exploring the structure of crystals and other substances has attracted great attention, more particularly after the researches of Sir David Brewster. Many substances, perfectly homogeneous when examined by the eye in the usual

manner, present the most beautiful and elaborate textures when they are examined with the assistance of polarized light.

2390. A ray of light, polarized in the usual manner by reflection, may be depolarized by transmission through certain media, as a thin film of mica or sulphate of lime. To observe this effect, let a ray of light from a candle proceed in the manner represented, and fall at the proper polarizing angle upon a piece of p¹ .e-glass having the back blackened ; and, on receiving the ref¹ected ray upon another similar glass, instead of being seen or looking along the dotted line, nothing will be noticed. If a p ate of mica or sulphate of lime be now placed between the two p ates at right angles to the polarized ray, the ray falling upon th₂ second plate appears and disappears at every quarter revolutions of the plate of mica as it is turned upon its axis, this having the power of depolarizing the ray when it meets it in particular positions.

Fig. 249.
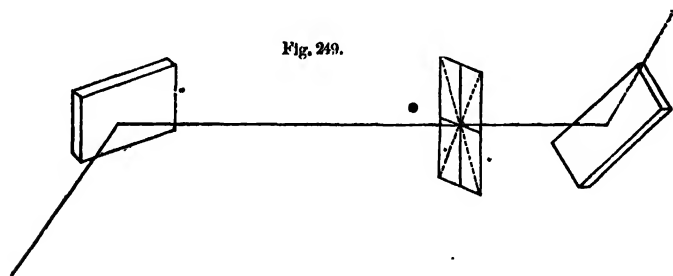
2391. The DECOMPOSITION of light may be effected by absorbing some of the rays by different media, while others are transmitted or reflected ; or, it may be produced by the influence of various substances that refract unequally the different rays of which white light is composed. According to the process adopted by Sir Isaac Newton in his great discovery of the composition of white light, a beam of solar light, $a\,b$, is transmitted through a small aperture into a darkened apartment, and made to fall upon a glass prism, $c\,d\,e$, as shewn in the figure (250). As it enters the prism at b, the different kinds of light are refracted unequally, and undergo a still farther refraction as they emerge from the side $e\,c$, producing an oblong coloured image upon the

opposite wall, which is usually termed the **Prismatic Spectrum**, the red being the least, and the violet the most refrangible ray. Sir Isaac Newton pointed out seven different colours in the

Fig. 250.

Violet.
Indigo.
Blue.
Green.
Yellow.
Orange.
Red.
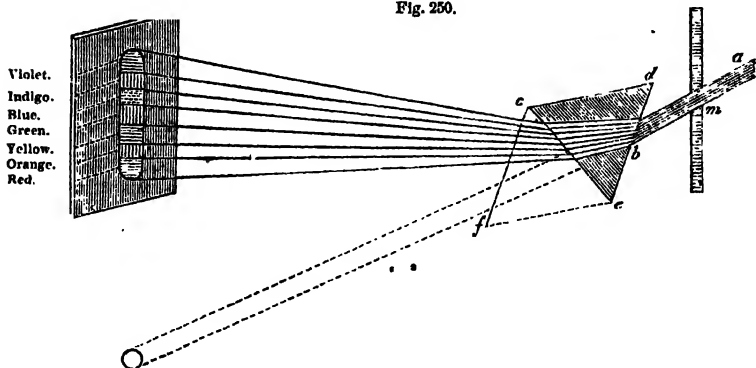
spectrum, but the later analysis of Sir David Brewster has proved that it consists in reality of three primary rays, viz. red, yellow, and blue, which, by their union in various proportions, form the other colours described in the Newtonian spectrum.

If another prism, cfe, be placed next the first, but with the apex upwards, as seen in the preceding figure, the glass in both being of the same quality, the ray of light, $a\,b$, will proceed as it emerges from the second prism, as if it had not been refracted at all, the light decomposed by the first prism being recomposed by the second.

2392. Sir David Brewster has also proved, that each of the three primary colours may be found in every part of the spectrum, but in very various proportions, each of them being greatly

Fig. 251.

in excess at particular parts of the spectrum. The red rays accumulate towards the lower part a (Fig. 251), the yellow rays b not far from the red, and the blue rays c at the other extremity of the spectrum. The general mode of distribution is indicated in the accompanying figure.

2393. Immediately below the red ray in the spectrum less refrangible rays have been observed, consisting of calorific rays

totally unaccompanied by luminous rays ; and above the violet ray, or immediately upon its extreme and upper edge, rays have been inferred to exist which are neither calorific nor luminous, but which are particularly distinguished by their chemical agency, having a powerful effect in darkening chloride of silver compared with what is observed in any other part of the spectrum.

2394. The luminous rays may generally be accompanied by heat, and, when absorbed, produce a calorific effect ; but experiments, in which the luminous rays were transmitted first through water, and then through glass coloured with oxide of copper, appear to prove, that the rays of heat may thus be altogether absorbed, and the luminous rays procured entirely void of any calorific power.

2395. The influence of light on chemical action is a subject that has been hitherto only very imperfectly studied. It is still, however, sufficiently marked in numerous well known instances ; and this has accordingly led to the opinion, that, were the subject minutely investigated, its action would be found to be general, and much more important and extensive than is commonly supposed. Its action on chloride of silver has been previously referred to. A bright sunshine causes the immediate detonation of a mixture of oxygen and hydrogen. Its powerful influence on the vegetable kingdom is acknowledged ; and, on the animal system, recent experiments and observations* have led me to entertain the opinion, that it is equally powerful.

2396. The very singular discovery announced lately in Paris, that a material has been discovered so susceptible of the influence of light, that any reflected image thrown upon it stains it permanently with an outline far beyond the pencil of art in accuracy and delicacy of detail, must probably depend upon the chemical agency of light upon the materials of which it consists.

2397. Many curious experiments have been performed by Dr Stark in reference to odorous matters, from which it appears, that dark coloured clothes absorb them and retain them with much more power than those of a lighter tint.

2398. It is now admitted that the rays of light have very various properties according to the source from which they ema-

* See Reply to the Right Honourable Lord Duncannon on the Ventilation and Lighting, &c. of the House of Commons. House of Commons' Reports, 1838.

nate, partly, perhaps, dependent on the peculiar impulse they may receive as they are emitted, reflected, or refracted, and partly on the heat, on the electric or magnetic influence that may be associated with them, or the precise nature of the molecules of ordinary matter with which they may come in contact. Hence the light of the sun, and ordinary terrestrial light produced by any common combustible, have different powers of penetrating screens of glass and other substances, and the heat associated with them is more apt to be absorbed by coloured glass, and influence accordingly any photometrical result.

2399. The most intense light that can be developed by artificial means is produced by transmitting a stream of galvanism through wires tipped with charcoal.* The Drummond Light comes next (called also Gurney's Light). It is usually produced

Fig. 252.
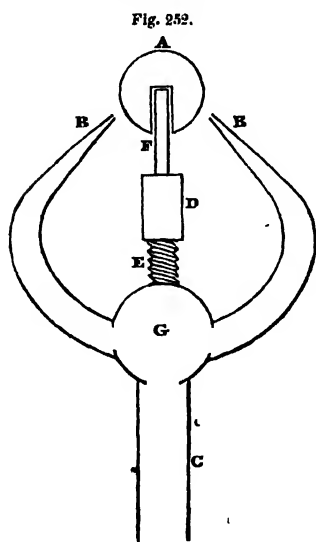
by mixing oxygen and hydrogen gases as they escape from separate gasometers, and directing the united streams upon a ball of lime, as in the annexed figure. A is the lime ball detached a little from its support, that it may be more distinctly seen ; B B two nozzles or jets discharging oxygen and hydrogen gases upon the lime, the hydrogen being in slight excess, and having been inflamed. The excess of hydrogen tends to sustain the light, with less danger of interruption from the momentary extinction of the flame. Though two jets have generally been employed, five, and even ten, have sometimes been used. C is the tube through which the mixed gases are supplied. D a brass cap, terminating in the platinum-support F, and screwing upon E, so as to admit of the ball being properly adjusted. G the central ball, to which the different jets are fixed.

*   See Galvanism.

2400. Fig. 253 represents the tube C, which supplies the mixed gases with the flexible tubes, M and N attached, which convey the oxygen and hydrogen from separate gasometers.

2401. In using the lime-ball light apparatus, an extreme variety of apparatus has been adopted, and arrangements provided for renewing the balls as they are exhausted by clock machinery. Fig. 254 represents an apparatus of the size required, but which, for ordinary experiments, may be supplied with five instead of two jets. The lime balls are turned out of a piece of fine chalk, and should be prepared larger than they are ultimately required, as the lime contracts on heating. The chalk is converted into lime by heating in a crucible, covering it with fragments of charcoal, so that none may be in direct contact with the sides of the crucible. The hydrogen gas alone should be kindled first, and in minute quantity only, till the ball is red-hot ; then it may be put on in full force, and supplied with oxygen. (See Oxyhydrogen Blowpipe.)

2402. A single jet may be employed if it be not necessary to illuminate the lime on every side, and a cylinder

Fig. 253.
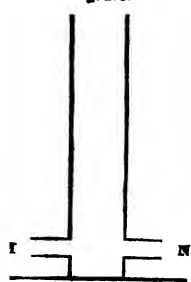
Fig. 254.
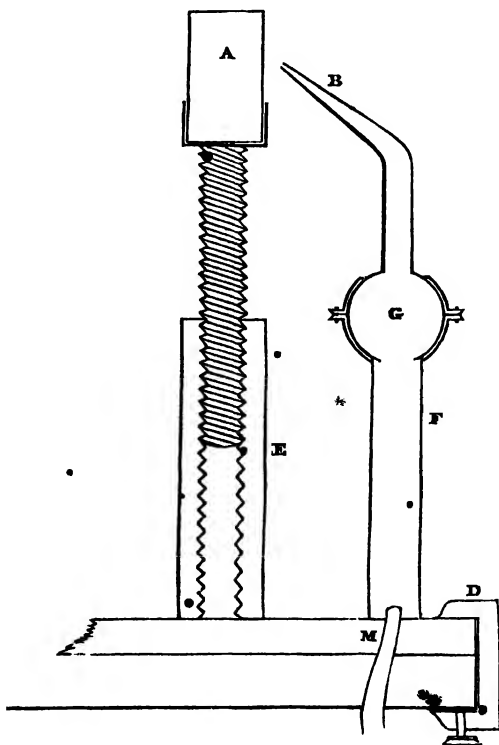
may be substituted instead of a ball, turning it round by a screw; or a special apparatus may be adapted for this purpose.

2403. I may also add, that I have long used coal-gas instead of hydrogen, more especially when using the single jet on a cylinder of lime, and have found it to do extremely well.

2404. The light produced in this manner may be seen at the distance of 90 or 100 miles, and is so extremely bright and brilliant, that it produces a prismatic spectrum in the same manner as the rays of the sun. Placed in the focus of a light-house reflector, a beam of light may be seen extending from it for miles in a dark night; and even at ten miles distance, if the hand be held before a wall, it produces a distinct shadow.

2405. If a lamp or candle be held near any wall upon which it may be shining at the distance of 50 or 100 feet, the outline of the warm air is distinctly indicated by the manner in which it refracts the light; and, in the image consequently produced upon the wall, no line of demarcation is observed between the extremity of the flame and the hot air ascending from it. A red-hot iron bar presents a similar appearance when substituted for the candle. The manner in which a feebly luminous flame produces intense light when it impinges upon some solids, has not been explained. The lime is slowly wasted by being converted into vapour; and apertures are often pierced through a stationary lime-ball, where the different jets play upon it. Small crystals of lime may also be occasionally seen deposited upon the surface of the lime, when it has for a long time been exposed to the flame of the mixed gases.

2046. A very high temperature is required to render gases luminous, so that it is not perhaps possible to observe them in this condition, except when in a state of combustion. If combustible gases be subjected to a less elevated temperature, they may often be made to act upon air, and sustain a slow combustion, by which metals, such as platinum, may be rendered redhot, while the gases that produce the heat may not be in the slightest degree luminous. Thus, a weak red light may be produced by placing a thin slip of platinum in the flame of a spirit-lamp, and transferring it into a jar in which a mixture of gas and air is made to rise. The red-hot platinum sustains an imperfect combustion between the gas and the air, by which the platinum is still maintained at a red heat. Should it be brought

to a white heat, the mixture
of gas and air is generally
kindled, after which the gas
generally becomes luminous,
and burns in the ordinary man-
ner. Fig. 255 shews the man-
ner in which the platinum is
suspended in the mixture of
gas and air, the gas rising
from the tube, and the air
entering around it.

Fig. 255.
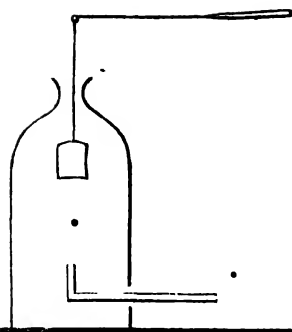
2406. If the thin platinum
foil be heated as before, and
then held over a little ether placed at the bottom of a glass jar, a
similar effect is produced. Mr Merryweather of Whitby has con-
structed lamps, having balls of spongy platinum placed over the
wicks, by which a dull red heat is maintained when the spirit
employed is kindled on them, and the flame extinguished. These
lamps may be used advantageously for giving a fixed temperature
for many days successively ; alcohol is the fluid generally pre-
ferred. Very thin platinum wire coiled round the wick may be
substituted for the platinum sponge.

2407. The evolution of light by PHOSPHORESCENT BODIES is
sometimes dependent on slow combustion, as when phosphorus
is freely exposed to the air in a dark apartment. On other occa-
sions light is emitted by phosphorescent bodies after the action of
light, heat, or electricity. Decayed animal and vegetable matters
often appear phosphorescent; and in the animal kingdom the
glow-worm, the fire-fly, and many animalculæ inhabiting the
polar seas, exhibit good examples of phosphorescence.

2408. Some substances which may have ceased to produce
light when heated, evolve it freely again when subjected to the
electric spark, as Mr Pearsal pointed out.

2409. The cause of phosphorescence in many cases is ex-
tremely obscure. In a number of cases, light appears to be ab-
sorbed from the sun, and again slowly evolved.

2410. PHOTOMÉTERS are instruments for measuring the in-
tensity of light. Leslie's photometer is composed of the differ-
ential thermometer, having one of the balls blackened, and is
constructed on the principle that the intensity of light is pro-

portional to its heating effect when absorbed. The extreme variety, however, in the calorific ·influence of different kinds of luminous bodies, prevents it from giving accurate results. In the more common varieties of photometers, the intensity of any light is indicated by the depth of shadow produced at a given distance upon any white ground by interposing an opaque object, comparing the shadow with that produced under the same circumstances by some standard light.

III. HEAT.

2411. Caloric is the term applied to the matter of heat, or the power or force by which it is produced; its nature is unknown; it has been regarded,

2412. I. As consisting in a peculiar motion or tremor of the particles of matter.

2413. II. As produced by vibrations or undulations in a peculiar elastic fluid or ether, as it has been termed, supposed to be universally diffused.

2414. III. It has been regarded as a subtile fluid, its particles being of extreme tenuity, invisible, imponderable, and repulsive of each other, whilst they attract those of other kinds of matter.

2415. Caloric is universally distributed throughout the globe, though the proportion in different places, and the amount in different kinds of matter at the same place, may be very various. Wherever it may be accumulated, it tends to diffuse itself amongst the surrounding objects, till an EQUILIBRIUM has been established.

2416. The TEMPERATURE of bodies is their condition with respect to heat when compared with some standard, as boiling or freezing water.

2417. ABSOLUTE CALORIC refers to the total quantity of heat which any substance at a given temperature may contain, a question that has not yet been solved.

2418. COLD bears the same relation to heat that darkness does to light; there is no peculiar frigorific principle. And as the darkness is greater and greater in proportion to the absence

of light, so cold is more and more intense in proportion to the absence of heat.

2419. The rays of the sun, and many natural and artificial operations, as well as the movement of the globe itself to varied distances from the sun, maintain a constant inequality of temperature ; were no such causes in operation, a uniform temperature would at last be attained.

2420. No power has a greater influence on matter than caloric ; the changes of the seasons, the alternations of day and night, and the effects it produces on the animal, vegetable, and mineral kingdoms, all attest the importance of its operation. In the great phenomena of nature, as well as in the more limited operations of art, it is always in action, sustaining the harmony of creation, and producing or modifying all the changes of which matter is susceptible. It is so subtile and penetrating that there is no matter into which it cannot enter, neither can it be accumulated and collected like ordinary kinds of matter and shewn by itself. No substance has ever been obtained free from it, nor have we any means of ascertaining what the form, size, or properties of matter would be, were it utterly deprived of heat.

2421. Till lately, it was not considered that heat could communicate a repulsive power to different substances, but recent experiments have given countenance to this opinion, more especially the very curious phenomena discovered by Mr Arthur Trevelyan, connected with the vibrations of various metals brought in contact with one another, each being at different temperatures.

2422. At first it was supposed that the vibrations were produced by the expansion induced in the colder metal at the point of contact, raising the superincumbent warmer metal and throwing it momentarily upon a new portion of the colder metal ; the first point cooling in the mean time, when the warm metal returns upon it, a second expansion takes place as before, and thus a continued movement is induced so long as a proper inequality of temperature is maintained. Professor Forbes, however, who has entered minutely into the consideration of this question, is of opinion that the phenomena are not explicable, except upon the assumption that caloric under certain circumstances can communicate powers of attraction and repulsion in the same manner as electricity.

2423. The vibrations are induced most conveniently by placing a bar of brass with a long handle upon a block or upon a cylinder of lead, in the manner shewn in the accompanying figures. The bar of brass may weigh from half a pound to five or ten pounds, and the block or cylinder of lead, from two pounds to one hundred pounds.
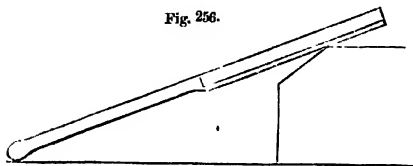
Fig. 256.

Fig. 257.
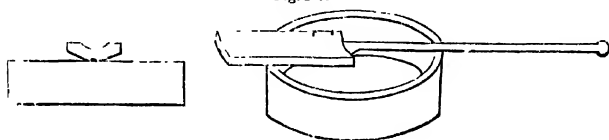
2424. Very deep and beautiful tones are frequently produced when these vibrations are induced in air (and the apparatus very large), resembling those of an organ. The slightest touch or pressure either on the table or on the metals produces a great variety in the effect. The vibrations may be made to communicate a rocking motion to any substance placed upon the bar, which will often continue though it be loaded with a weight of ten or twenty pounds, according to the size of the apparatus.

2425. The brass should not be heated so much as to melt the lead, and one of the most convenient methods of preparing it for action consists in heating it till small fragments of lead soften upon its surface. If it be then removed from the fire, in a few minutes afterwards, it is generally fit for use. The bar should be kept bright and clean and free from smoke.

2426. In Fig. 258, a section is given of a brass bar such as is frequently used, a small groove being made below to facilitate the production of the musical tones.

Fig. 258.

2427. The investigations of Professor Forbes have shewn that Heat can be polarized in the same manner as light, and new facts are almost daily presenting themselves in respect to its nature and properties, shewing how great a field of investigation is still open to the inquiries of science.

CHAPTER I.

EFFECTS OF HEAT.

2428. The most important general effects of heat are *Expansion*, *Liquefaction*, *Vaporization*, *Incandescence* or *Ignition*, and its effect on chemical action. It also can excite electricity and magnetism.

SECT. I.—EXPANSION.

2429. The amount of space which any given portion of matter may occupy, is usually dependent upon the quantity of heat associated with it. Further, all substances are in general expanded by heat, and contracted when it is more or less withdrawn. The mode in which this expansion or contraction is produced, is not precisely known ; the caloric is supposed to insinuate itself between the particles of bodies as they expand and remove them to greater distances, or at least to induce some change in their position, in consequence of which the mass occupies a larger space. Individually, the particles are not supposed to augment in volume. This takes place only in the masses which they compose.

2430. The greater the cohesion of bodies, the less in general is their expansion from a given increase of temperature. Gases and vapours expand much more than liquids and solids. Air is augmented about 3–8ths of its volume, mercury 1–55th, and hammered iron 1–273d, when heated from 32° to 212°.

2431. Solids and liquids expand with extreme force when heated. Gases when heated have less proportional expansive power in consequence of their great compressibility. Tenacious solids, such as iron, expand with great force on the application of heat, and contract with great power as they cool.

2432. The expansion of bodies by heat is not permanent, except the heat be retained by which it was originally induced. Hence also, the volume of all substances is subject to perpetual fluctuation according to the temperature. Again, heat having no appreciable weight, if indeed it has any, the specific gravity

or density of all substances is affected by their temperature. See Specific Gravity.

2433. In Solids and Liquids the expansion of different bodies is extremely dissimilar, none almost being expanded to the same amount by the same increase of temperature, whether we compare solids with solids, liquids with liquids, or solids with liquids.

2434. Again, the greater the temperature the greater the amount of expansion from a given increase.   Thus mercury in rising—

> From   32° to 122° = 90 degrees.   The Ratio of Expansion 14.
> From 122° to 212° = 90 degrees.   Ratio of Expansion 15.

But many substances are far less equal in the amount of expansion.   Thus in water

> From   32° to 122° = 90 degrees.   The Ratio of Expansion 4.7.
> From 122° to 212° = 90 degrees.   Ratio of Expansion 15.

2435. In Gases the expansion is very uniform, all gases expanding alike from the same increase of temperature ; this amounts to 1–480th part of their volume at 32° for every degree of Fahrenheit's thermometer.

2436. Procure a round bar of iron, whose length is measured accurately by an iron gage, and which can be barely passed through a round aperture at the extremity of the gage.   Heat it to redness, and observe that it cannot now be included between the extremities of the gage, nor can it be passed through the round aperture.   Cool it in water to its former temperature, and then observe that it has returned to its original volume.

2437. Put a thin glass flask with a long narrow neck into a glass or jug of boiling water, after filling the body with coloured spirit of wine.   Observe how rapidly the spirit is expanded and rises in the neck.   Cool it, and allow it to return to its former volume.

2438. Fill a flask 1–3d or 1–4th full of water, inverting it afterwards in a basin of water in the manner shewn in Fig. 62, page 39, but placing the supporting ring below, instead of above the body of the flask.   Pour boiling water upon the flask, and notice the rapidity with which the air expands, which returns again to its former volume on cooling.   If part of the air be expelled by the expansion, the water will necessarily fill more of the flask on cooling than at first.

Movements produced by Expansion in Fluids, in consequence of an Alteration of Specific Gravity.

2439. Few subjects are of more importance in explaining many of the phenomena of nature and processes of art, than the alteration of specific gravity induced by the application of heat. It changes the power of resistance between the substance heated and that which receives no augmentation of temperature, the colder sinking under the warmer and specifically lighter body, pressing it upwards, arriving thus itself at the source of heat, and becoming expanded in its turn, after which it is pressed up by a succeeding portion, this movement being continued so long as any inequality of temperature is maintained. On the large scale perpetual currents are thus induced in the waters of the ocean, the general tendency of which is to transfer the warmer water of the equator to the poles along its surface, while a returning cold current moves from the poles to the equator at the bottom of the ocean. In the atmosphere, the same general movement prevails; and nothing is a more frequent source of wind than the movements induced by alternations of temperature. The following practical illustrations will assist the student in becoming more familiar with this subject, and they should be compared with the illustrations of furnaces and fire-places given in page 144, &c.

2440. Apply heat to a glass-vessel containing water in the manner shewn in the annexed figure. The water in contact with the warm glass expands, the colder water in the centre descends; and the circulation is continued in this manner so long as any inequality of temperature is maintained.

Fig. 259.

2441. Pour into two tubes a strong coloured and cold solution of litmus, or of any other light vegetable colouring matter. Heavy metallic solutions will not do for this experiment. Pour upon this with extreme caution, boiling water to the height represented in Fig. 260, taking care not to disturb the position of the litmus. Allow the liquids to cool till both shall have attained the same temperature with the air. Then heat the upper portion of one of the tubes till the liquid boils. No currents are induced. The water may be boiled away in considerable quantity, without the slightest

movement being seen below. The specific gravity of the fluid being diminished above, it still tends to remain there. Let the

'Fig. 260.
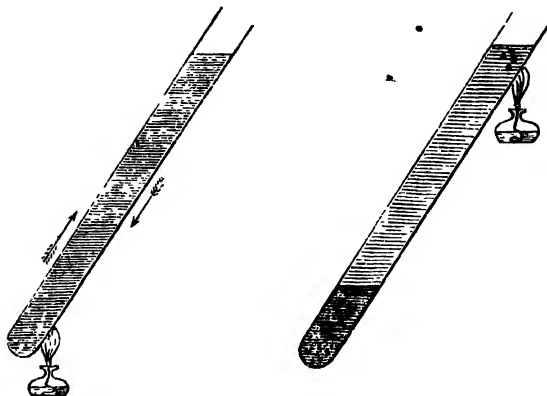
lamp be now applied to the lower part of the other tube ; the coloured liquid there immediately expands, the colder colourless liquid descends, the currents move as the arrows indicate, and in a short time the whole liquid appears of the same tint.

2442. Let a bent glass-tube be filled with water till it is full, and placed under water in a trough or cistern, till another smaller bent-tube, also full, is inserted in the first, in the manner shewn in the Figure. Let it now be well dried, and a lamp be applied to the lower part of one of the limbs. Currents may now be seen, which continue to flow, as pointed out by the arrows, so long as any inequality of temperature is maintained. If the lower part be filled with coloured litmus water, as in the preceding experiment, the circulation is more distinctly seen.

Fig. 261.
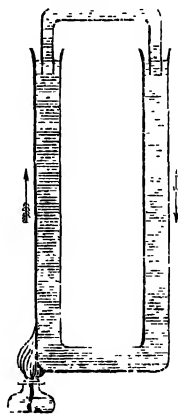
2443. In the same manner, boilers of metal are now constructed on the large scale, with tubes proceeding from them, by which hot water can be conveyed to any apartment, so as to diffuse heat in the same manner as a stove, returning to the source of heat when cool, and advancing again as before to sustain a proper elevation of temperature.

2444. In some cases a higher temperature is communicated to the water than 212°, by confining it in strong tubes, so that it is subjected to considerable pressure. Fig. 262 illustrates Perkins's heating apparatus formed on this principle. The water is heated in a coiled tube exposed to the fire of a furnace, and the tube leading the water away from the coil extends into another coil, wherever it is required to evolve its heat. *a* is the pipe for introducing the water, and *b* the expansion-tube, which it is necessary to have in this apparatus.

Fig. 262.
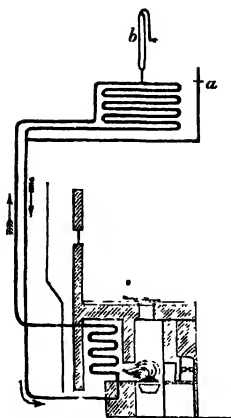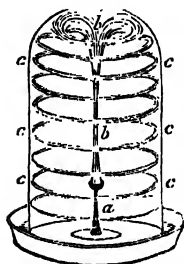
2445. Kindle some sulphur on a small

Fig. 263.

support, put over it a glass-jar or shade, as in Fig. 263, having filled it previously with oxygen, and observe the currents moving continually in the direction *a b c*; the warm air being pushed up in a central stream by the cold surrounding air, cooling in its turn as it reaches the top, and then descending in the form of rings surrounding the internal ascending current.

2446. In large apartments heated without any attention to the operation of currents, warm air may often be seen introduced at a central opening in the floor, (Fig. 264,) rising in a direct stream to the ventilator in the ceil-

Fig. 265.

Fig. 264.
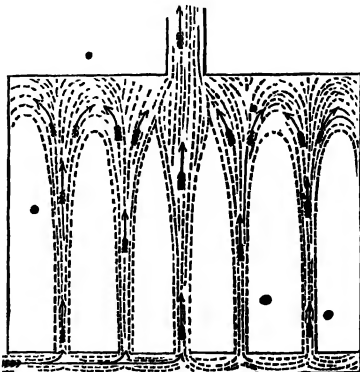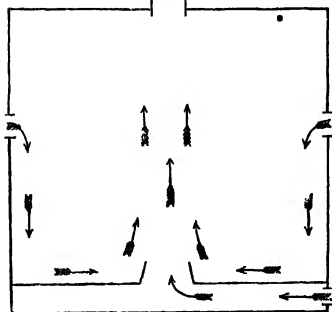
ing, where it escapes, while cold air may be at the same time
falling down in a stream from the windows, descending upon
those who may be next the walls, even though the windows be
shut, in consequence of the air within being cooled by contact
with a large surface of glass, or by the cold air admitted at the
crevices when they are not made air-tight.

2447. If warm air be admitted into an apartment by several
apertures (Fig. 265) instead of one, still, if its temperature be
considerable, it will tend to rise at once to the ceiling and escape
by any ventilator there, so that the air on the floor may be very cold excepting that in the immediate vicinity of the apertures, while above it may be oppressively warm.

Fig 266.
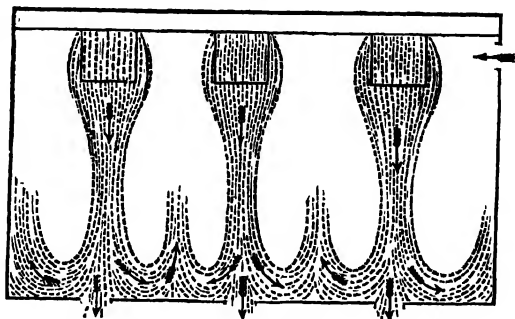
2448. If the discharge at the ceiling be not proportional to the air which can be supplied, then, as in Fig. 266, a considerable recoil will take place, and a more uniform temperature be attained. In this case, the apartment is supposed to be heated by cases supplied with hot water, the ascending current being determined by their being in contact with the surrounding air.

Fig. 267.
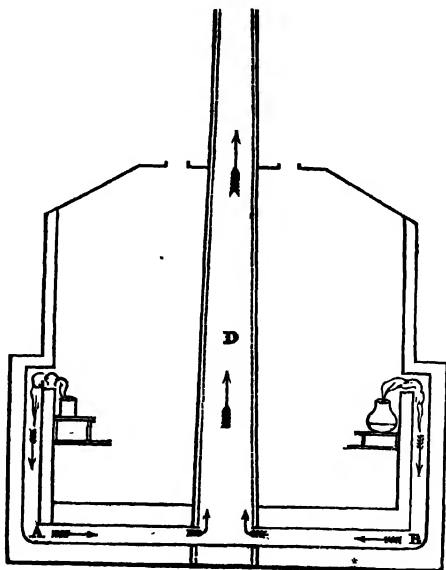
2449. In performing chemical experiments, as well as in all cases of ordinary ventilation, no-

thing is so convenient and economical for determining a steady and equal movement of the air as a draught induced by a furnace rarifying or expanding the air. Hence, a chimney is useful, not only with the view of producing intensity of heat in furnace operations, but also as affording an exit for any acid or other vapours which it may be desirable to remove. Fig. 267 shews the general arrangements of the ventilating flues in his Grace the Duke of Roxburgh's experimental laboratory at Floors. The ventilating flues extend through the walls, so that an opening at any part enables fumes to be at once carried off. The flues in the walls terminate in underground flues, which lead to the chimney. Fig. 268 shews the disposition of the underground flues.
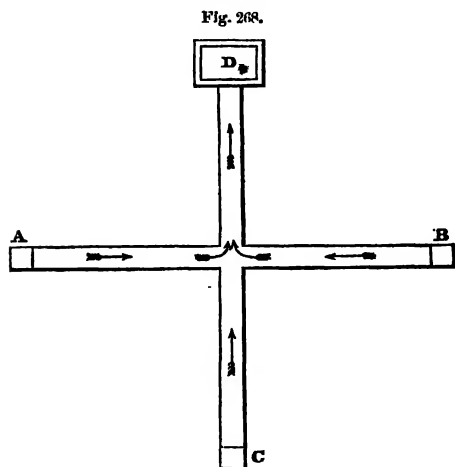
Fig. 268.

Fig. 269.
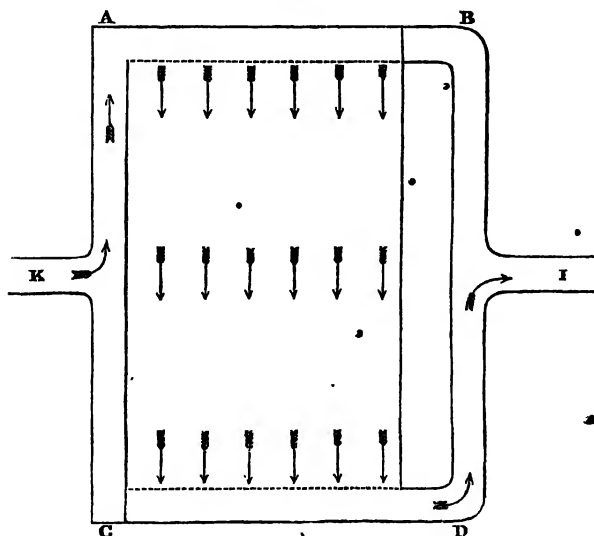
2450. The experiments on Respiration and Ventilation, referred to in preceding pages, were conducted principally in apartments or wooden boxes, in which a given quantity of air was admitted by a tube K, the respired air being carried away in general by another tube I, by which it was conveyed to a chimney. In the figure, the current is represented as entering at the roof, and proceeding to the floor ; but, by opening the closed valves at B and C, and shutting those at the opposite corners A and D, the currents may be reversed. It will be obvious, accordingly, that the air could be made to circulate, either by connecting the tube I with any ordinary chimney, or by propelling it with fanners or bellows at K.

Fig. 271.
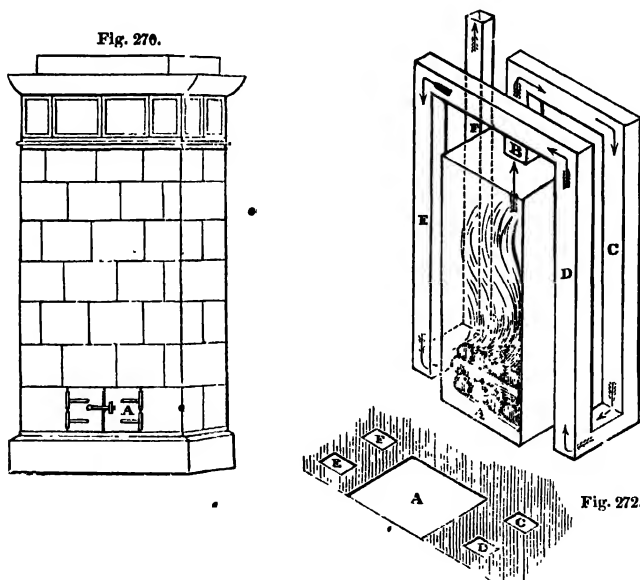
Fig. 270.

Fig. 272.

2451. In the stoves used in many parts of Northern Europe, more especially in Sweden, Russia, Prussia, &c., they have the form seen in Fig. 270, the fire rising to the top of an apparatus usually made of earthen ware, and extremely large ; it then descends on one side, rises on the same side again, crosses to the other side, descends and ascends as before, and is ultimately carried away to the chimney. Fig. 271 shews the position of the flues ; and, in Fig. 272, a ground-plan is given, the letters

indicating in succession those through which the heated air or smoke passes in the interior before its heat is exhausted. A damper regulates the supply and escape of consumed air.

2452. In Dr Arnott's stove, the circulation of warm air produced by the combustion of fuel is maintained for a long period within the body of the stove, and its heat is thus exhausted in a great measure before it escapes into the small chimney attached to it ; but, in an ordinary open fire-place, a large portion of heat escapes by the large chimney, and hence the comparative economy of this mode of producing heat, which, like the stoves of more Northern Europe, does not permit the waste smoke to escape till its heat shall have been withdrawn. From the figure (273) it will be observed, that, while the great mass of the gaseous products circulate within the stove, a small portion of fresh air is perpetually entering to sustain the combustion of the fuel, while a proportional quantity of vitiated air escapes.
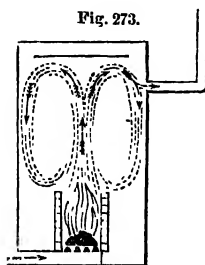
Fig. 273.
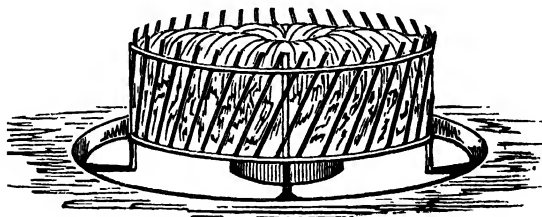
Fig. 274.

Fig. 275.
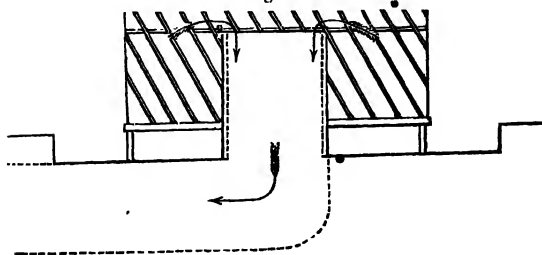
2453. Figs. 274, 275, illustrate the general appearance and construction of a fire-place in my experimental class-room, which

I have now used for a number of years.   It is three feet in dia-
meter, and the vent or chimney in the centre descends as the
arrows indicate, the tendency of the gaseous products of com-
bustion in immediate contact with the fuel to ascend being over-
come by the still greater expansion in the large chimney, to
which the underground flue leads.   This fire-place gives an ex-
tremely powerful heat ; and the heat still associated with the
gaseous products of combustion, is in a great measure exhausted,
as in the Swedish or Russian stove, by being led under the floor
before it escapes into the large vent.   The ash-pit is sunk six
inches under the floor.   Nothing tends more to diminish the
power of any fire-place than placing it considerably above the
level of the floor.   Coke alone is used in the above fire-place.   In
Fig. 129, page 148, it may be seen to the left in connection with
the vent or chimney into which the products of combustion are
carried.   Should the vent not be already warm, it is necessary to
kindle a few shavings in it, and produce an ascending current,
before it will draw.

2454.   The ventilation of mines affords a good illustration of
the movements induced in air by the expansion attendant upon
the communication of heat to air, the denser and unexpanded

Fig. 276.
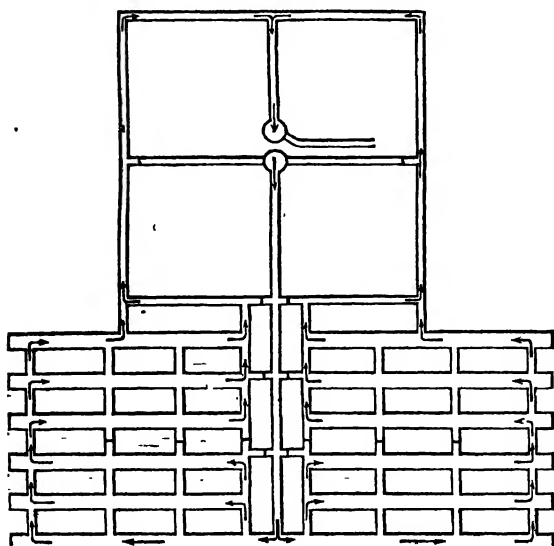
air sinking below, and pushing upwards the warm air produced at the bottom of one of the shafts of a mine by the action of a large fire. Thus, in the accompanying figure (276), shewing the ground-plan of a coal mine, two shafts or pits are represented by the two circles, the air descending by the more central shaft, and moving, as the arrows indicate, to the farther extremity of the mine. It then returns according to the course marked by the arrows, being led ultimately to a second shaft, in which it ascends the furnace by which it is heated, and which is the cause of the draught being placed as it passes to the bottom of the last shaft, or rather through an aperture in the side, a little above the bottom. The annexed figure shews the position of the furnace.

2455. Instead of two shafts, one shaft only is sometimes used, being divided into two, as in the annexed perpendicular section

Fig. 277.
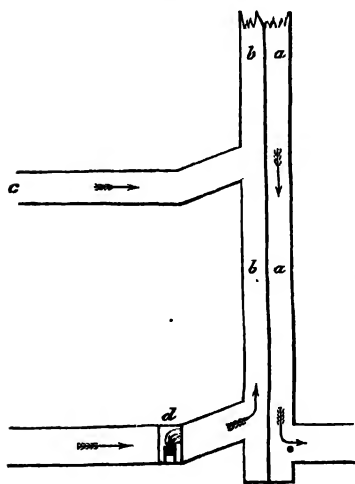
(Fig. 277). *a* indicates that half by which the air descends, and *b* the other through which it escapes after it has traversed the mine. The furnace is observed at *d*. When the gas or fire-damp evolved in any part of the mine is so concentrated that it might inflame at the furnace, and thus explode the mine or set it on fire, a communication is then made between that part of the mine and the shaft, more or less above the place where the air from the furnace passes into the shaft, as at *c*, by which it is removed without any danger of accident.

2456. Fig. 278 is a ground plan illustrating the progress of the air in a mine where the air-course has been divided by a partition, to admit of the air proceeding in the manner represented. In digging pits, they are often found, in particular situations, to fill rapidly with carbonic acid. The ground in some places appears to be saturated with carbonic acid; and any pit or excavation then becomes a cavity into which the carbonic

Fig. 278.
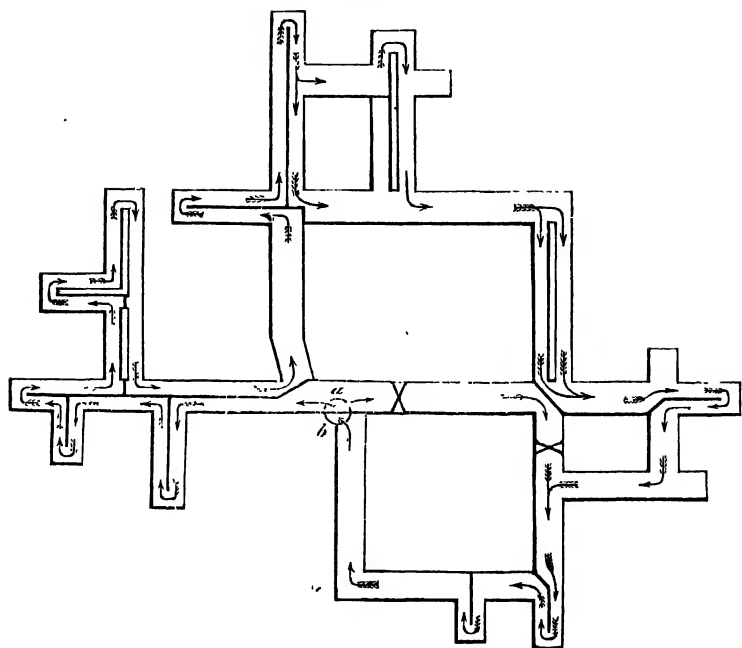
acid gas rapidly flows, in the same manner as water fills any or-
dinary well.   Even in digging grave-pits, the carbonic acid often
accumulates so as to prove dangerous to the grave-diggers ; and
of late, several fatal accidents have arisen from this cause.

2457. The grave-pits at London, Manchester, and some other
places, are often in some of the churchyards made of large size,
thirty, fifty, and even a hundred bodies, being occasionally placed
in the same grave, which in such cases is generally made about
thirty feet deep, seven long, and two or three broad.   In exa-
mining some of these, I have found at times, even before any
burial had taken place, the air so largely impregnated with car-
bonic acid for twenty-two or twenty-three feet above the bottom
of the grave, as to be incapable of supporting combustion or
respiration.

2458. A fanner or bellows might, in such cases, be employed
for renewing the air, or the air may be made to circulate in the
manner detailed in the preceding examples.   In one of the grave-

Fig. 279.
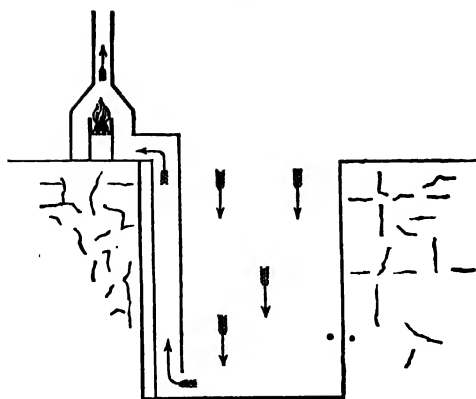
pits above referred to, a small moveable stove of sheet-iron was placed at the side of the grave, and a flexible hose, or wooden tube, depending from it (Fig. 279), drew up continually the offensive atmosphere, the carbonic acid being thus so diluted with air, as not to extinguish the fire. The fire can also be directly supplied with a portion of pure air, when this is necessary. The tube is extended as the depth of the grave-pit is increased.

Exceptions to the Law of Expansion by Heat.

2559. I. Water, at a temperature between its freezing point and 39.38°, presents one of the most curious exceptions to the law of expansion. Dr Hope's experiments proved, in the most unexceptionable manner, this curious anomaly ; and Hälstrom shewed, that it commenced precisely at 39°.38′ of Fahrenheit. In Dr Hope's experiments, thermometers were suspended at the top and at the bottom of a tall cylindrical jar, provided with a circular vessel externally, by which heat could be communicated or withdrawn from the liquid in the middle of the jar. If the water in the jar be at 39.38°, and a freezing mixture at zero be applied outside, as in Fig. 280, as the water falls in temperature it expands,
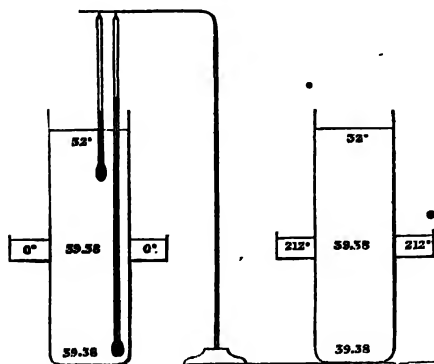
Fig. 280.

and rises to the top, the thermometer there indicating cold. But if the jar be filled with water at 32°, and boiling water be applied where the freezing mixture formerly was, then the cold water receiving heat becomes specifically heavier, and descends, this anomaly continuing till all the water shall have attained the same temperature. The movements of water in lakes and rivers present many curious fluctuations in consequence of the law that has now been mentioned. Sea water is not subject to this anomaly, the saline matter it contains altering its relations to the influence of heat.*

2460. Among the other exceptions to the law of expansion by heat, the following more particularly may be noticed.

2461. II. The contractions of Rose's fusible metal† between 110.75° and 155.75°.

2462. III. The more permanent contraction of clays by heat, these not recovering their volume on cooling.

2463. IV. The expansion of many fluids as they congeal. Iron, and other metals which have this property, take nice and accurate impressions as they cool. Even water expands with extreme force as it congeals, bursting rocks on the great scale, and, in artificial experiments, bursting hollow vessels of metal, or other materials, in which it may have been included.

2464. V. The angles of solids are often altered during the action of heat, as Mitscherlich has shewn, so that a body may in some cases expand in one direction and contract in another. Thus, it may become longer and narrower, or shorter and broader, instead of increasing in length, breadth and thickness.

Thermometer and Pyrometer.

2465. The sensations give only very imperfect information as to the condition of bodies in reference to caloric, and there are few precise observations which have been made without the assistance of the thermometer, or some corresponding instrument. In the common thermometer (Fig. 281), a glass ball, round or elongated, is filled with mercury, which extends into

* This subject has been investigated by Blagden, Marcet, Erdman, and Dr Hope. See Edin. Philosoph. Transactions for 1839.

† Composed of one of lead, one of tin, and two of bismuth.

the stem. To fill the ball, part of the air is in the first place expelled by expansion, and then the open extremity is plunged in mercury, which rises in the stem, and partly fills the ball. By boiling the mercury thus introduced, so as to expel the air, and again plunging the stem in mercury, the ball and the stem are filled with warm mercury, the skill of the glass-blower enabling him to exclude all air-bubbles; after which the mercurial tube is HERMETICALLY SEALED, by melting the glass at the upper part with the blowpipe flame.

2466. The thermometer is graduated by placing it first into ice-cold water, and afterwards into boiling water, marking the place where the liquid remains stationary in each case, and dividing the intermediate space into smaller spaces or degrees. In this country the space between the freezing and boiling points, which are ascertained in the manner mentioned, is usually divided into 180 degrees.

2467. The beginning or ZERO of the scale is 32 spaces below the freezing point; and, as it was soon ascertained, that much lower temperatures not only existed at the surface of the globe, but could easily be produced by artificial means, a series of descending degrees are made by continuing to mark off spaces below zero, equal in size to those above, the sign — being placed before them. Degrees both above and below the freezing point are produced in the same manner, viz. by marking off equal spaces above or below these points.

2468. It will be obvious from the preceding circumstances, that whether the thermometers have large or small balls, and long or short stems, still if graduated in the manner described, they must all give the same indications as those represented in the figure 282, where three thermometers very different in size are supposed to be exposed to the same temperature.

2469. A different system of graduation is followed in constructing some thermometers, more especially in those used on the Continent, where Reaumur's and the
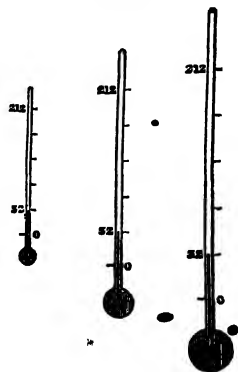
Centigrade are usually preferred. In Reaumur's, the space

Fig. 283.
Reaumur's.   Centigrade.   Fahrenheit.   De Lisle's.
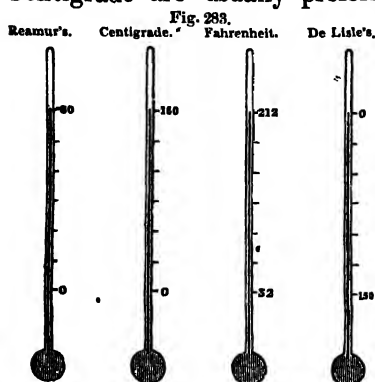
between the freezing and boiling points of water is divided into 80 degrees. In the Centigrade, the same space is divided into 100 degrees, and in De Lisle's into 150 degrees. In the latter, the zero or commencement of the scale is at the boiling point, and it rises to the freezing point, which is accordingly 150 degrees.

2470. Mercury is preferred in making ordinary thermometers, as its boiling point is high, its freezing point low, and its expansions comparatively regular, from equal increments of heat. Towards its boiling point, its expansions are greater than at a lower temperature, but these are fortunately very nearly counterbalanced by the increased capacity of the glass bulb at a high temperature. For very low temperatures, spirit of wine must be used, as mercury is frozen at — 40°, or 39.5.

2471. Sanctorio, the inventor of the thermometer, employed a very different instrument from that now in use. It consisted of a glass ball, Fig. 284, terminating in a long stem ; part of the air having been expelled by heating the ball, the stem was placed in a coloured liquid, which rose in it till the contracted air had attained the temperature of the surrounding air. A warm day expanded the included air, and the liquid descended in the stem. By cold, the air was contracted, and then the pressure of the atmosphere forced the liquid higher than formerly.

Fig. 284.   Fig. 285.
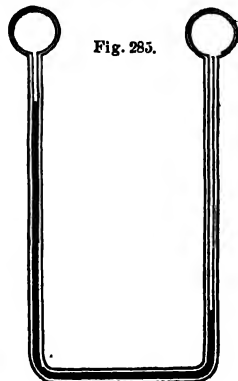
2472. The DIFFERENTIAL thermometer, Fig. 285, consists of two balls connected by a tube, which is partly filled with a coloured liquid. When exposed to heat or cold, no change ensues, the balls being equally af-

fected, but if one ball be exposed more than another, a change then ensues, the liquid always rising in the stem where the ball is comparatively cooler, and descending from the other or warmer ball.

2473. REGISTER THERMOMETERS of many different kinds have been invented, some of which are worked by clock apparatus, and record all the varying temperatures that may be observed within a given time. Others again, more simple in their construction, express only the highest or lowest temperatures that may have taken place. In Rutherford's Register Thermometers, the highest temperature is indicated by the distance to which a small portion of steel-wire within the tube of the thermometer is pushed during the expansion of the mercury, and left as the mercury retires. In the accompanying illustrations, Fig. 286 shews the

Fig. 286.
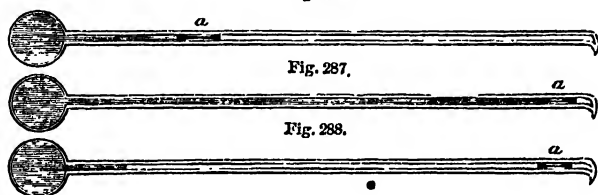
Fig. 287.

Fig. 288.

thermometer set for an observation; Fig. 287 represents it at a high temperature, the steel-wire being pushed forward by the mercury; Fig. 288 shews the steel-wire resting in the same position after the mercury has returned as the temperature declined.

2474. For registering low temperatures a spirit of wine thermometer is employed, a piece of enamel being floated or supported at the upper part by the spirit, Fig. 289. As the tem-

Fig. 289.
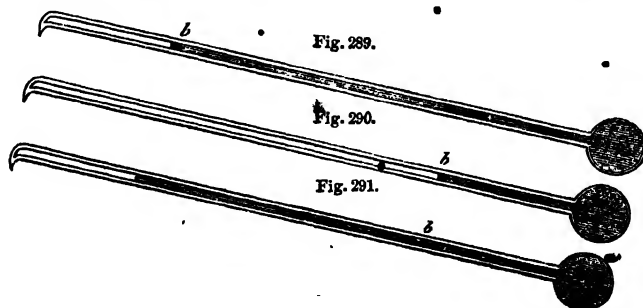
Fig. 290.

Fig. 291.

perature falls, the spirit descends, the enamel sinking along with it, Fig. 290.   But when the temperature rises, the enamel remains stationary at the point to which it had descended, Fig. 291, indicating the greatest cold that had taken place since it had been set.

2475. Instruments for measuring high temperatures are usually termed PYROMETERS.   Of these, the most important is that invented by Professor Daniell, by which the temperature is ascertained by the expansion induced in a bar of platinum or iron. Guyton Morveau proposed a similar method.   These instruments being more complicated and expensive than thermometers, have not come into general use, but their importance is beginning to be appreciated more and more, and there are few things that would assist more in the progress of chemistry than the discovery of any method by which high temperatures could be measured with the same facility as ordinary temperatures are ascertained with the common thermometer.

2476. Wedgwood's pyrometer was formed of a bar of brass having grooves which were narrower at one extremity than at the other; with it the intensity of heat in any furnace was estimated by the amount of contraction induced in small pieces of clay, this being ascertained by the extent to which they passed along the grooves after they had been subjected to heat.   But the impossibility of procuring pieces of clay of the same quality, and the circumstance that a long continued low heat has been found to produce the same effect as a high temperature during a shorter period, proved insurmountable objections to its general use. '   '

2477. Sir J. Herschel's ACTINOMETER, derived from αχτιν the sunbeam, is a very delicate thermometer by which the intensity of the action of the rays of the sun is measured apart from the cooling influence of surrounding objects.   It has a large bulb made of transparent glass, which is filled with a dark blue liquid, and by observing the comparative effects produced—1. When exposed in the shade for one minute, 2. When exposed to the rays of the sun for the same time, 3. When again exposed in the shade ;—the actual influence of the sun upon this instrument for one minute is determined by subtracting the mean of the two indications in the shade, from the amount induced on direct exposure to the sun.

2478. By soldering bars or leaves of metals of unequal expansibility, very delicate instruments have been constructed for indicating minute changes of temperature. When they are used as thermometers, they must be graduated by comparing the movements induced in the bar with the expansions in the common thermometer. One extremity of the bar is fixed, and to the other is attached a moveable index ranging along a graduated scale.

LIQUEFACTION.

2479. Two elements only are liquid at natural temperatures, viz. Bromine and Mercury. But the liquid condition is accidental, and dependent on the heat present in bodies and their peculiar relation to caloric. It is universally admitted, accordingly, that all solids may be regarded as frozen liquids, and all gases and vapours as evaporated liquids.

2480. All solids, as they are melted by heat, consume or absorb caloric without being elevated in their temperature. This heat is said to become LATENT, in the language of Dr Black, who made this important discovery, and is often termed also COMBINED or INSENSIBLE caloric, as it does not affect the thermometer. It is equally returned during consolidation without any reduction of temperature.

2481. The melting point varies extremely in different substances. Alcohol is fluid at the lowest temperatures hitherto produced.

2482. In vacuo, it is affirmed that a much lower temperature than usual is required to effect the congelation of water, but that the moment it commences, the latent heat evolved escapes so quickly as to elevate immediately the temperature of the remaining fluid to the ordinary freezing point.

2483. The amount of latent heat required for the melting of each individual solid is generally very various. That required for melting ice would elevate the temperature of an equal weight of ice-cold water 140 degrees.

2484. Were there no latent heat required during the melting of solids, nor any evolved during the congelation of liquids, matter would be extremely prone to change its form suddenly the moment it attained a particular temperature ; but the large quan-

tity of latent caloric required for liquefaction, and that evolved
during the freezing of water, equally tend to mitigate the ex-
treme heat and cold that would be otherwise observed at the
surface of the globe. The same cause prevents frequent inun-
dations from being produced by the sudden liquefaction of ice
and snow, and large quantities of ice from being locked up sud-
denly in the solid form, by the immediate congelation that
would otherwise attend a reduction of temperature to the freez-
ing point.

2485. Liquids present many curious phenomena dependent
upon the extreme mobility of their particles.   Less cohesion is
observed in them than in solids, and so great is the facility of
movement in the particles, that they pass at times even through
membranous bodies in opposition to their natural gravity, as in
cases of EXOSMIC and ENDOSMIC action, where an INWARD and
OUTWARD movement of liquids may be traced through membra-
nous matter, or even through porous earthy substances.   Thus

Fig. 292.
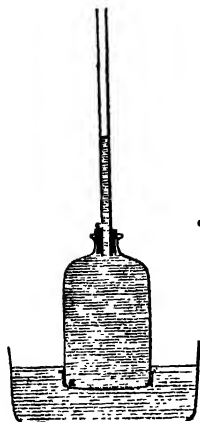
if a portion of milk and sugar be introduced
into a bottomless jar, Fig. 292, a tube rising
from the tubulure, and the bottom of the jar
being covered carefully by a piece of mem-
brane, a portion of the milk slowly exudes,
but a larger quantity of the water enters, if
it be placed under water as shewn in the
figure. The fluid to which the membrane or
other interposed matter is most permeable,
always moves towards the others, the viscid
liquid combining with it as it enters.   An
electric action is also considered to take place
in many cases, and facilitate the movement.
Dutrochet, whose experiments and observa-
tions led to the discovery of this curious sub-
ject, has published a number of interesting details as to these
exosmic and endosmic movements, which are considered to ex-
plain many facts in the history of the animal, vegetable, and
mineral kingdoms.

Sect. III. Vaporization—Gases--Spontaneous Evaporation.

2486. Vaporization is the rapid production of a thin and attenuated vapour from a liquid by the direct action of heat. Some solids pass at once to the .gaseous condition, without previous liquefaction, and others have their melting and boiling points so near, as camphor, that if a small portion be heated in a tube, at the same moment part may be observed melting on the application of heat, another part boiling, and a third part condensing in a solid form from a state of vapour.

2487. Bodies that are converted into vapour with facility are said to be VOLATILE; those that require a high temperature are usually termed FIXED.

2488. Great expansion usually attends vaporization. Water expands 1696 times its bulk, calculating from its point of greatest density. Hence it would explode like gunpowder were a large quantity to become vaporized at once.

2489. Dr Black shewed that a large quantity of heat becomes latent as water is converted into vapour, viz. (according to the average of different calculations) about as much as would elevate the temperature of an equal weight of water by 1000 degrees were it still to remain liquid. The long time required for the supply of this large amount of heat, prevents much water being evaporated at once, and hence, in ordinary ebullition, there is no violent explosion.

Fig. 293.

2490. All liquids obey the same law as water in passing to a state of vapour, but the quantity of heat that becomes latent in each is very different.

2491. To illustrate the expansion attending vaporization, fill a glass bulb terminating in a long tube with water, and then introduce a portion of ether, and, before it disappears, by combining with the water, pour boiling water freely upon the glass bulb, supporting it on the ring of a retort stand. The ether soon expands to a great degree as it is converted into vapour.

2492. All fluids do not expand in the same degree, when they are vaporized. Alcohol expands
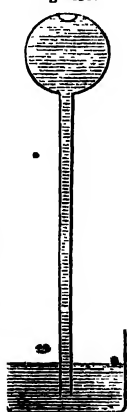
so much less than water, that its vapour is heavier than that of water, though, in the liquid form, it is specifically lighter.

2493. VAPOURS resemble gases, but are rendered fluid with comparative facility. They are extremely elastic, condensing as they are subjected to pressure, and expanding as they are relieved from it, in the same manner as gases.

2494. The process of DISTILLATION depends upon the different volatilities of different substances, so that by the application of a cautiously regulated temperature, those that are more volatile are converted into vapour, while the others are left.

Fig. 294.

2495. The apparatus commonly employed for distillation is the still.and refrigeratory. See page 33. The still is often surmounted by a dome or head, as in Fig. 294, which assists in guarding against any tendency in the materials in the still to boil over, by condensing the less volatile vapours as they arise.
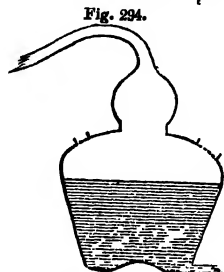
Fig. 295.

2496. A more conical form, Fig. 295, is found to be more economical, as it does not require so much heat to keep it at a proper temperature. The fire must be very carefully attended to in all cases of distillation.
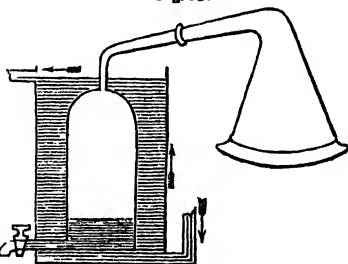
2497. In the distillation of spirituous liquids from fermented fluids, an extreme tendency to produce froth has been observed, the addition of a small quantity of soap has been found to diminish in many cases the tendency of such fluids to boil over.

Fig. 296.

2498. The refrigeratory has been made of very various forms; it is commonly constructed in the manner referred to, page 33, or as seen in the adjoining figure, the tube receiving vapour from the still being represented by the dotted line, and surrounded by cold water placed in the containing vessel. It may now, however, be frequently observed of a very
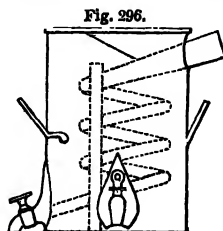
different form, as in Fig. 297, where the part in which the va-
pour is condensed may be seen surrounded on every side by a
stream of water ascending from below, from A by C, and escap-
ing above by B, as its temperature is elevated by the vapour *a*,
which it condenses. In Fig. 295, a very strong condenser is ob-
served entirely surrounded with water.

2499. The vapour is also frequently condensed by a series of
receivers, as in Fig. 298, where the more volatile portions are
procured in the receiver most distant from the still.

Fig. 297.   Fig. 298.
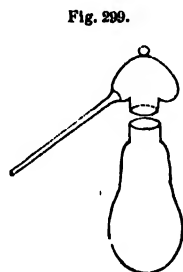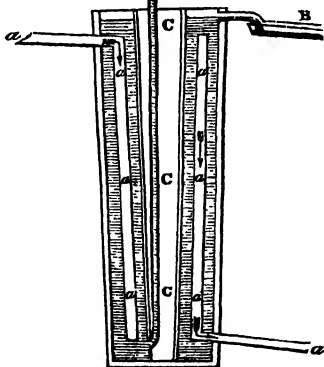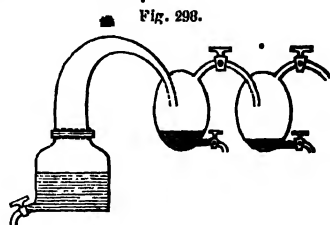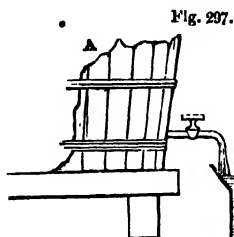
Fig. 299.

2500. When a solid is deposited instead of a liquid in the con-
densation of vapour, it is said to be SUBLIMED, and the process
is termed SUBLIMATION. On the small scale, a flask, a retort, or
a glass cucurbit may be used. It consists of two parts, Fig. 299,
the upper portion condensing the sublimate, and any liquid se-
parated during the process being removed by the spout.

2501. The boiling point of different fluids is influenced by the
nature of the vessel in which they are subjected to heat. Water
boils at a temperature about two degrees lower in metallic than
in glass vessels. The vapour appears to escape more easily in

metallic vessels, especially if they be rough inside. Fill a glass flask nearly full of boiling water, and apply heat so that the water shall boil.   Remove it from the heat, and when the ebullition has completely ceased, throw in some iron filings, a few small nails, or a small piece of a metallic chain ; in general, a brisk ebullition immediately commences, the metallic matter facilitates in a greater degree the production of vapour by the nature of the surface it presents, than it opposes vaporization by the heat it withdraws from the warm fluid.

2502. Many other solids produce similar effects.   Some solutions in ether and alcohol boil at a temperature nearly 30° or 40° lower than usual, when mixed suddenly with solid substances in a minute state of division.   '

2503. All vapours are transparent, but some are coloured of various tints, as iodine, nitrous acid, &c.   When exposed to cold they are condensed with explosive rapidity, and the latent heat they contain is evolved, so that they part with much heat as they change their form without falling in temperature.

2504. Introduce into a glass or other vessel full of water, a tube connected with a boiler producing steam, the tube being so narrow, and the steam coming so quickly, that there shall be no danger of regurgitation.   The steam is condensed suddenly, and with a loud noise as it enters the cold water, from the movements induced by it in the water, and the subsequent collapse of the water as the steam is condensed.

2505. Take two equal portions of cold water, and condense steam into one of them till it be heated to 212° ; weigh the amount to which it is now increased by the condensation of the steam, and add to the other an equal weight of boiling water. The steam heats the cold water much more than the boiling water, communicating heat not only in consequence of the excess it had as boiling water, but also all beyond this which was essential to its existence as steam.

2506. INFLUENCE· OF PRESSURE.   A number of illustrations of the influence of pressure upon the production of vapour having been given under the history of water and atmospheric air, it will be sufficient here to state the more important facts in reference to this point.

‹ 2507. At 212° boiling water .produces steam, having barely sufficient elasticity to overcome the pressure of the air and rise

against it.   Water does not attain a higher temperature under ordinary circumstances, as the steam then escapes, carrying along with it all excess of heat communicated to the water.

2508. If steam be produced in a boiler, and then be prevented from escaping by shutting all the apertures, it is compressed by the succeeding steam that is formed, if the heat be still continued.   The degree of compression is proportionate to the amount of new steam produced, and the area into which it is forced.   The steam thus becomes denser and denser, it presses more and more upon the water in the boiler, and the temperature rises higher and higher.   Accordingly,

The greater the PRESSURE to which it is subjected,
The more elevated the TEMPERATURE required to produce it,
The greater its DENSITY, and
The greater its ELASTICITY or pressing power.

Hence the PRESSURE exerted by vapour may be inferred from its density or temperature,—its density from its pressure or temperature, and its temperature from its pressure or density.*

2509. Steam is always of the same temperature with the water from which it rises, though in numerous cases where it is affected by local circumstances, a great fluctuation in different parts of the same apparatus may be observed, especially when it is very complicated, as in the locomotive engine.

2510. The density or elasticity of steam increases in a greater ratio than the temperature.   Thus it is,

1† at 212°	4 at 293.7	16 at 398.48
2 at 250°.5	8 at 341.78	24 at 435.56

2511. When the steam is very dense, it is termed high pressure steam, and presents, in this condition, some peculiarities. In particular, if allowed to escape from the containing vessel, it instantly expands, becomes cold, ceasing to be high pressure steam, and produces a cloud of vesicular vapour, mixed with air and moisture from the condensed steam.   The hand placed in this mixture is not scalded, and hence the origin of the familiar saying, that high pressure steam does not burn the hand, though, in reality, it ceases to be high pressure steam before it reaches

* See Table of Elastic Force of Vapour.
† Equal to the pressure of one atmosphere.

Fig. 300.
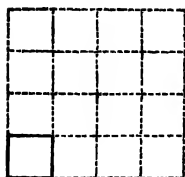
the hand. If the square figure (300) surrounded by the plain lines represent steam having sixteen times its previous density, and consequently at a high temperature when it escapes into the open air, it will immediately expand to a great degree, occupying sixteen times the space it did before, represented by the dotted lines; and accordingly, it is obvious that the caloric, which kept it at a high temperature within the boiler, will no longer be able to do so when it is diffused over so much more space.

2512. A reduction of pressure facilitates vaporization, vapour being then formed at a lower temperature. According to Professor Robison, when fluids are entirely relieved from pressure, they boil at 140 degrees below their usual boiling point. If ether (sulphuric) be placed in an ale-glass (Fig. 301), and relieved from the pressure of the air, by placing it in the air-pump receiver, and exhausting the air, it boils with rapidity at natural temperatures, and produces so much cold by the latent heat carried away in its vapour, that water may be easily frozen in this manner in a tube, by placing it as represented in the figure.

Fig. 301.
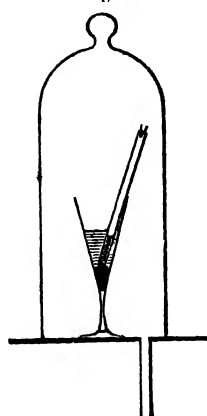
2513. The quantity of heat that becomes latent varies with the temperature; the greater the temperature, the less the latent heat. The total amount of heat in steam appears to be always the same, whether formed in a steam-engine boiler, or by evaporation from the surface of the ocean. Hence, there is no economy of fuel in distilling at a low temperature, but other advantages often result, as when water is to be evaporated from any matter which might be apt to be decomposed at its ordinary boiling temperature.*

Arrangements adopted for Vaporization.

2514. On the small scale, an endless variety of processes may be resorted to for producing vapour, the general nature of which

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* See water and atmospheric air, for distillation at low temperatures, &c.

will be sufficiently understood from the experiments and pro-
cesses described in former parts of this work. The following
illustrations refer more especially to the modes adopted for pro-
ducing vapour rapidly in very large quantities.

Fig. 302.
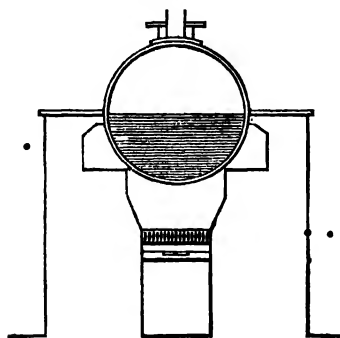
Fig. 303.
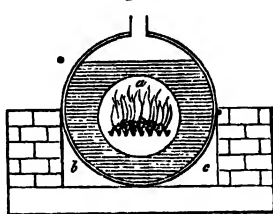
2515. Fig. 302 represents one of the more common modes of
heating a boiler, the fire being placed below, and the flame and
hot air from it afterwards circulating round it before it escapes
into the chimney.

2516. In Fig. 303 the fire is observed in the interior of the
boiler, instead of being placed below it as in the preceding case,
circulating afterwards round the boiler by *b* and *c*.

2517. Again, in Figs. 304, 305, and 306, the arrangements
adopted in some marine boilers are shewn, by which steam is
generated very quickly from the large heating surface brought
into play.

Fig. 304.
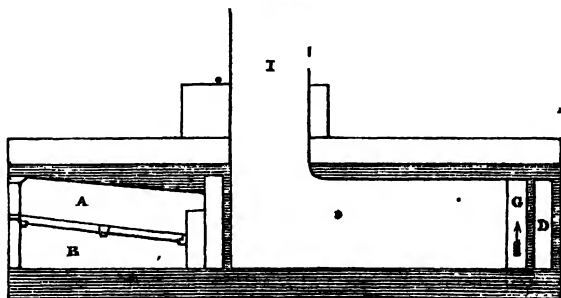
Fig. 304 is a longitudinal section of the boiler, the fire resting

on the furnace bars at A, the water in the boiler being above and below the fire, as well as on either side. Several of the letters refer to all the three wood-cuts. I is the principal chimney.

Fig. 305 is a ground plan, illustrating more particularly the movement of the hot air from the furnace through a third part, viz. the central division of the boiler before it terminates in H, which leads to the small branch chimney *b*, forming the central third of the large chimney I, Fig. 306. I receives also *a* and *c* from the other divisions of the boiler not seen in Fig. 305.

Fig. 306 gives a transverse section of the chimney with the flues *a*, *b*, *c*, as they proceed from the separate parts of the boiler.

Fig. 305.
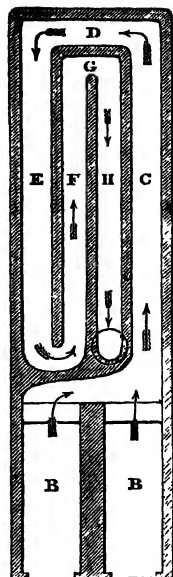
Fig. 306.
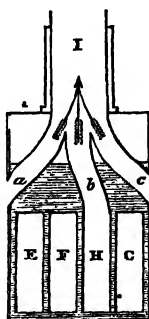
2518. Where a large quantity of high pressure steam must be produced within a small area, the arrangement adopted in Stephenson's locomotive engine is considered the best. Fig. 307 shews a transverse section of the fire box surrounded by the boiler containing water, and the extremities of a series of tubes which convey the hot air through the rest of the boiler to produce more steam. In Fig. 308 a longitudinal section of the fire box is given, and also of the rest of the boiler, shewing part of the tubes as they communicate with the chimney. The progress of the steam from B may be traced by *b* and *c* to D, the piston to be moved by its impulse, while the steam on the other side escapes by a course (partly concealed) to F, from which it is projected into the chimney. The more quickly the steam is projected into the chimney, the more rapidly does the fire burn, the draught being greatly increased by the mechanical impulse communicated to the air in the chimney.
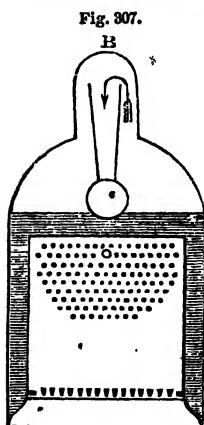
Fig. 307.
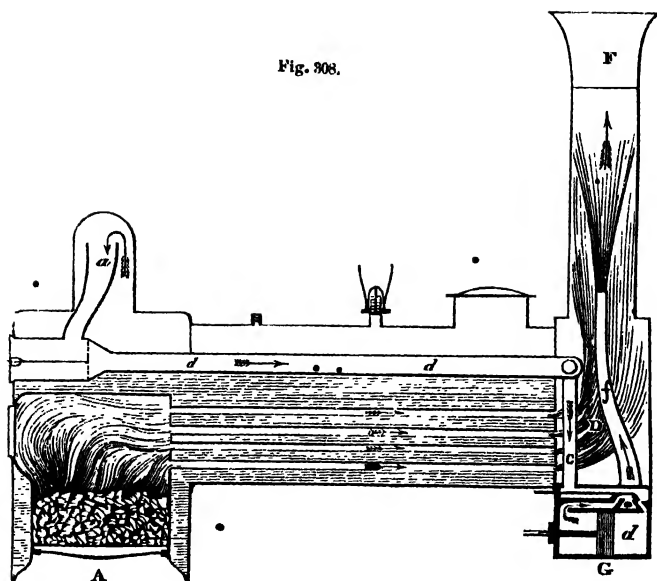
Fig. 308.

2519. In numerous operations, heat is communicated so as to evaporate liquids by high pressure steam, a tube from a high pressure boiler traversing any fluid in an open tank or cistern.

Fig. 309.
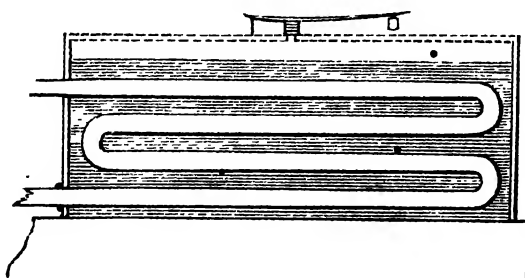
2520. Instead of operating in this manner, Mr Goodlet uses a high pressure boiler as an enormous water bath (Fig. 309), the liquid to be evaporated being made, with the assistance of a force-pump, to traverse the boiler, arranged as above with a safety-valve. It produces vapour with great rapidity from the

large area at a more elevated temperature, with which water can thus be brought so quickly in contact.

2521. If the object be not so much to produce steam for any

Fig. 310.

special purpose, but rather to dissipate water from any solid in solution, the liquid is usually heated in an open pan or boiler, or the flame may be made to sweep over its surface after placing it on the floor of a reverberatory furnace.   Page 242, Fig. 176.
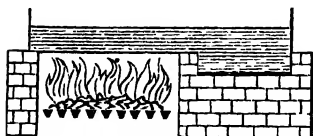
2522. If the evaporation be conducted with the view of boiling

Fig. 311.
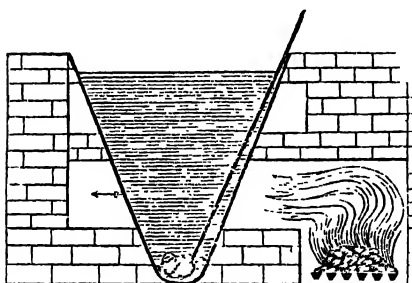
away the water from a concentrated solution of salt, a pan (Fig. 310) or boiler (Fig. 311) is often constructed or built up, so that the salt, as it is deposited, may rest upon a part not exposed in any way to the direct action of the fire, and from which matter it may be gradually removed from time to time by ladles and baskets, as it accumulates.   Were it permitted to fall upon a hotter part of the boiler it would be apt to form a hard crust, and the iron might be injured by the heat of the furnace.

GASES.

2523. Gases are now considered as the vapours of fluids which boil at so low a temperature, that they remain permanently in the gaseous condition under ordinary circumstances.   Air accordingly may be regarded as a vaporized liquid.   It is, at ordinary temperatures, already beyond its boiling point.   No attempts have hitherto succeeded in reducing oxygen, hydrogen, or nitrogen, to the liquid form ; but Dr Faraday pointed out, that many other gases could be condensed into liquids with the assistance of great cold and pressure.

2524. The usual method of proceeding consists in introducing the materials required for the production of the gas to be tried

into a glass-tube, of the form represented in the annexed Figure (312). The tube is sealed hermetically; and the materials being

Fig. 312.
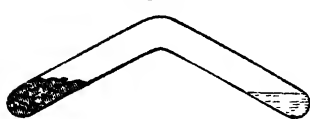
mingled in one extremity, which had previously been kept separate, the condensed gas appears in the other, which is generally kept very cold. Occasionally, as in preparing liquid cyanogen, one material alone is introduced into one end of the tube. In this case the bicyanide of mercury is employed; the cyanogen is expelled by heat, and condensed in the other extremity of the tube.

Table shewing the Temperature and Pressure required to Liquefy the following Gases :—

Gases.	Pressure.	Temp.	Gases.	Pressure.	Temp.
Sulphurous Acid,	2	45	Sulphureted Hydrogen,	15	50
Cyanogen, .	.3.6	45	Carbonic Acid, .	36	32
Chlorine, .	4	60	Muriatic Acid, .	40	50
Ammonia, .	6.50	50	Nitrous Oxide, .	50	45

2525. Carbonic acid gas has been condensed in larger quantities than any other. It is a transparent and colourless liquid, and evaporates with extreme rapidity when relieved from pressure. It produces, as it evaporates, the greatest degree of cold hitherto observed; and part of it is frozen by the cold arising from its own evaporation. In this condition it resembles snow, and may be easily handled, notwithstanding its exceedingly low temperature, in consequence of its bad conducting power. I have retained portions in my mouth for a considerable period before they were dissipated : it does not melt, but passes slowly to the gaseous condition. ·

2526. Thilorier was the first who prepared large quantities of carbonic acid, and rendered it solid. For this purpose it is usually collected in a large receiver, and becomes solid as it escapes when the stop-cock is opened. Mr. Addams has constructed an improved apparatus for preparing it, which he described at the Newcastle Meeting of the British Association. Dilute sulphuric acid and sesquicarbonate of soda are often used in preparing it. The annexed Figure (313) represents the mode in which it has been prepared by Mr Smith. *a a* is an extremely strong cast-

iron vessel,* containing fragments of carbonate of lime ; *b*, the aperture by which they are introduced ; *c*, a force-pump by which muriatic acid may be made to ascend through the fragments of carbonate of lime ; *d*, the receiver in which the carbonic acid is collected. By appropriate stop-cocks, more carbonate of lime may be introduced, and the muriate of lime already formed withdrawn. The carbonic acid is liberated as the muriatic acid takes the lime, and gradually becomes liquid as it accumulates in the receiver.

Fig. 313.
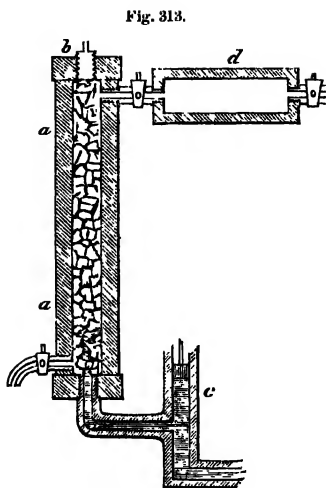
2527. Some of the gases not hitherto condensed have been subjected to a pressure equal to eight hundred atmospheres ; and, in carrying on such experiments, it has been ascertained, that the amount of condensation when liquefaction does not ensue is not in every case proportional to the pressure, as had been formerly maintained. Sulphurous acid, hydrosulphuric acid, ammonia, and cyanogen, are not reduced in bulk in the same ratio as atmospheric air when subjected to the same pressure.

2528. Condensed gases may be used as a powerful means of producing extreme cold. Solid carbonic acid mixed with sulphuric ether freezes mercury quickly as it evaporates. The ether improves the conducting power of the carbonic acid. Thilorier produced a reduction of temperature of — 185° by the evaporation of the carbonic acid.

DIFFUSION OF GASES.

2529. If a bottomless bottle be tightly corked, filled with water, and placed upon the shelf of a pneumatic trough, it may then be used as a pneumatic jar in the following experiment. Fill it half-full of oxygen, and then cautiously fill it up with carbonic acid gas, while it rests upon the shelf or stool of the pneumatic trough. Then remove the cork, and introduce a suspended

* The iron vessel is protected internally from the acid by lead.

candle. It burns brilliantly in the upper stratum of oxygen, but is extinguished in the carbonic acid below, being kindled again as it is drawn upwards into the oxygen. Hence, gases of different densities do not mingle rapidly with each other, at least to any great extent. But if the oxygen and carbonic acid be left together for a considerable time, they gradually diffuse themselves through each other, part of the heavy carbonic acid rising, while a portion of the lighter oxygen descends.

Fig. 314.

If two gases be taken still more dissimilar in their specific gravities, as hydrogen and carbonic acid gases, the same general result is obtained. By placing the lighter gas in a bottle, which is inverted over the other, with the carbonic acid, as in Fig. 314, connecting them by a narrow tube, greater obstacles are opposed to any mutual diffusion; but part of the light hydrogen descends, while the carbonic acid ascends.

2530. According to Dalton, who was the first to enter upon this very curious investigation, one gas acts as a vacuum to another. The particles of any gas repel each other; but the particles of one gas do not repel those of another. These views, however, have not been generally entertained, and there is considerable diversity of opinion as to the causes of the diffusion of gases through each other.

2531. Dobereiner has shewn, that hydrogen escapes in some cases through a small crack in a glass-jar standing over a pneumatic trough, and with so much force, that the water rises to the height of one or two inches, or more. Professor Graham, in extending his researches on this subject, ascertained that air always enters as the hydrogen escapes, and has introduced the term DIFFUSION VOLUMN, to express the peculiar diffusive power of each individual gas, which depends upon its specific gravity.

Fig. 315.

2532. In many of Professor Graham's experiments, tubes open at one end, and closed at the other with plaster of Paris, were employed. They may be filled with the gases by introducing a long tube, in the manner shewn in Fig. 315; the atmospheric air being expelled by the introduction of a

Fig. 316.

large quantity of gas, while the tube is slowly with-
drawn.   It is necessary to adopt this or some other
mode by which the plaster of Paris shall not be
moistened.   Professor Graham uses a bent tube, ar
in Fig. 316, and then depresses the whole in wates
till the air in the experimental tube shall have been
expelled through the bent tube, after which it is re-
moved and the gas introduced, the small quantity of
atmospheric air not extracted having been carefully
noted.   In experimenting over mercury the above
precaution is unnecessary.

2533. Fig. 317 represents one of Professor
Graham's diffusion tubes in action after being filled
with hydrogen gas, &c. A, the extremity closed with
the plaster of Paris; B, the water into
which the open end of the tube is
placed; C, the height to which the
liquid may have risen in a given time.
A tube from six to twelve inches long,
and half an inch, or an inch in diame-
ter, is sufficient for these experiments.

Fig. 317.
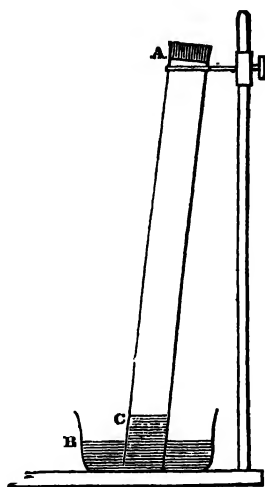
2534. Gases diffuse themselves with
very various degrees of rapidity, hydro-
gen and other light gases diffusing
themselves much more rapidly than at-
mospheric air. According to Professor
Graham, " gases should rush into a
vacuum, with velocities corresponding
to the numbers which have been found
to express their diffusion volumes, that
is, with velocities inversely proportional
to the square root of the densities of
the gases."

2535. Gases may be diffused through many substances besides
dry plaster of Paris; but in some cases, as in permeating through
membranous bodies, absorbable gases at least are considered to
unite with the substance of the membrane or water contained
in it, and then to be transferred to the opposite side from that
at which they enter, evaporating subsequently from it. It is

generally agreed, that gases must be condensed or liquefied before they can pass through liquids.

2536. Drs Mitchell and Faust have ascertained many interesting facts as to the passage of different gases through membranes· Ammonia is most rapid in its movements, while the same quantity of carbonic oxide is 160 times longer in permeating the same membrane. Great force is also exerted in permeating membranes. A bladder, half-full of air, expands when placed in an atmosphere of carbonic acid standing over water, and is often burst if it be left there for a long time. In general, the more readily gases are condensed by water, the greater the facility with which they pass through membranes.

SPONTANEOUS EVAPORATION.

2537. Spontaneous Evaporation is a term usually applied to designate the production of vapour by some natural agency without the direct application of heat. In considering it generally, we shall include those cases where it takes place without ebullition, even though it may be assisted by a moderate application of heat.

2538. Moisture is supposed to diffuse itself through the air when evaporated, in the same manner as gases diffuse themselves through each other.

2539. Many fluids and solids evaporate at natural temperatures, and, from the moistened surface of the earth, as well as from the ocean, water is almost continually evaporating or undergoing a kind of natural distillation, and forming that vapour which is returned again as rain, snow, hail, dew, or hoarfrost.

2540. It was a common opinion at one time, that minute quantities of vapour were continually emanating from all bodies at the surface of the earth, but Dr Faraday's experiments have not supported this view.

2541. CAUSE OF EVAPORATION. Dalton has shewn that heat is the great cause of evaporation. In the same space the same quantity of water evaporates whether air be present or not, other circumstances being equal. Evaporation takes place more rapidly *in vacuo* than in air, but not to a greater extent. Evaporation goes on more quickly in a current of air than in a stagnant atmosphere, the superincumbent moisture being swept

away by the current, and an opportunity afforded for further evaporation.*

2542. Great cold is produced by liquids as they evaporate. Water and many other fluids may be frozen by the cold produced by their own evaporation. Where water is used for this purpose, it may be placed in a porous earthen cup in the manner recommended by Sir John Leslie, supporting it as in the

Fig. 318.
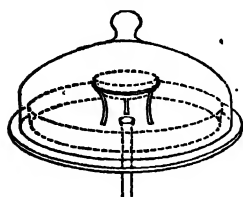
annexed (Fig. 318), in a broad shallow dish containing sulphuric acid, the whole being placed on the plate of an air-pump, and covered by a glass receiver. As the receiver is exhausted, part of the water evaporates, and is condensed by the acid, and at last the remaining water is frozen.

2543. Spontaneous evaporation is much influenced by a number of circumstances, especially, 1. The volatility of the evaporating substance; 2. The temperature; 3. The pressure; 4. The condition of the superincumbent air in respect to moisture; 5. The extent of surface from which the evaporation proceeds. The influence of the air has been already adverted to. The more volatile any substance is, the more rapidly does it evaporate. The greater the extent of surface also, the greater the evaporation.

2544. TEMPERATURE. The higher the temperature, the greater the evaporation. The terms TENSION, FORCE, or ELASTICITY of vapour, signify the force with which vapour presses or resists pressure; and the higher the temperature, the greater is the tension, and consequently the density of the vapour, exactly in the same manner as in vaporization.† The following table shews the elasticity or pressing power of the vapour of water at different temperatures below its boiling point, the elasticity being measured by its power of supporting a column of mercury; the height is expressed in inches.

Temp.	Elasticity.	Temp.	Elasticity.
32	0.200	145	6.53
52	0.401	173	13.02
73	0.796	205	26.13
96	1.63	212	30.00
119	3.25		

The elastic force of vapour below the boiling point of water, is

* See Water, Water-hammer, Cryophorus.
† See Vaporization.

estimated most conveniently by introducing a little water into a barometer tube filled in the usual manner, heating the barometer tube afterwards to various temperatures, so as to observe the degree to which the mercury is depressed.

2545. Pressure. Spontaneous evaporation is influenced in the same manner by pressure as vaporization. The illustrations under water and atmospheric air, with the water-hammer, pulse glass, cryophorus, distillation in vacuo, &c. sufficiently explain this subject. See also paragraph 2542. Pressure retards and opposes evaporation, but when the temperature is constant, the same amount of moisture is always found in the same space, according to Dalton, whatever be the pressure.

2546. In common language, moisture in the air is said to be dissolved or combined with it, but in a more strict sense, the moisture may be said to be diffused through the air in the same manner perhaps as gases are diffused through each other.

2547. From the amount of moisture always diffused through the air by spontaneous evaporation, it is always necessary to dry it carefully before it is employed in all precise experiments. This is usually effected by passing it over chloride of calcium, which attracts the moisture. Thus, before any portion of air or gas is weighed, it is usually introduced into a

Fig. 319.
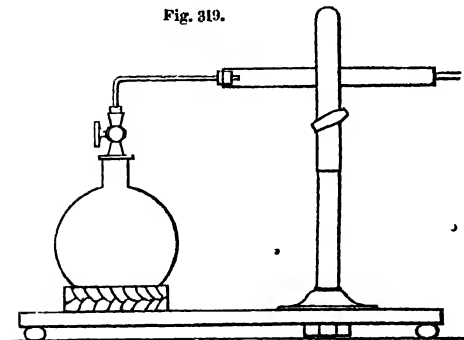
flask of the form represented in Fig. 319, after it has been exhausted of air, the gas or air that enters being made to pass slowly through a tube attached to the flask in the manner shewn, after it has been filled with chloride of calcium in small fragments. Instead of chloride of calcium, any other substance having a powerful attraction for moisture may be used.

2548. Again, in drying any substance at a fixed temperature, air dried by passing it over chloride of calcium in small fragments, is often made to pass over the subject of experiment, this being arranged in the manner shewn in Fig. 320, a, is a crucible chauffer with a triangular frame of iron supporting the

vessel ; in *b* water or any other fluid may be maintained at

Fig. 320.
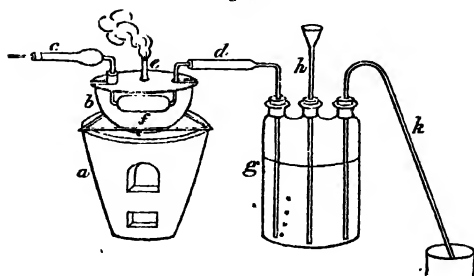
a constant tempera-
ture ; *c*, the tube for
the chloride of cal-
cium by which the air
is dried ; *f*, the ap-
paratus for contain-
ing the matter to be
dried ; *k*, a syphon-
tube by which the
water is slowly re-
moved from the ves-
sel attached to *f*, when the atmospheric air necessarily follows
in the course *c f d g* ; *h*, a funnel for introducing more water,
when the syphon is removed, that the air may be expelled.

2549. Air is charged to a much greater extent with moisture
in summer than in winter, but this is not so perceptible in con-
sequence of the superior temperature rendering it much less
prone to deposition.

2550. HYGROMETERS are instruments for ascertaining the con-
dition of the air as to moisture.   Of these instruments a great
variety have been contrived ; the following are the most import-
ant varieties.

2551. 1. Many substances alter their volume much when ex-

Fig. 321.
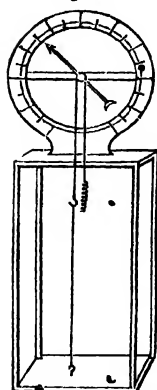
posed to dry and moist air, such as a human
hair, a small thread of whalebone, the beard of a
wild oat, or a piece of catgut. To convert any of
these into a hygrometer, a portion is taken of a
given length and kept in air saturated with mois-
ture till it undergoes no farther change of vo-
lume.   Its length is then noted upon a gradu-
ated scale, and compared subsequently with its
length after being kept in air absolutely dry till
it is no longer affected.   In this manner, the
extreme points are laid down indicating the
greatest amount of dryness or moisture, and the
space between them is usually divided into 100
degrees.   The fibre employed is usually kept
stretched with a moderate weight. The Fig. 321
represents DE LUC'S WHALEBONE HYGROMETER, a small spiral
circle of wire is attached by a hook to the whalebone, and moves

the index, as the latter expands or contracts. The temperature must always be carefully attended to in estimating the amount of moisture in the air.

2552. 2. Daniel's Dew-point Hygrometer, Fig. 322, con-

Fig. 322.
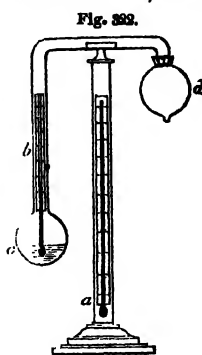
sists of a small cryophorus containing ether *c*, in one of the balls, and a thermometer *b*, immersed in it. The empty ball is surrounded with muslin, and on pouring ether on it, the vapour of the ether in the interior is condensed, and more evaporates quickly from the other ball, producing cold which is indicated by the thermometer *b*. The ball with the ether is then carefully examined, and the moment dew appears deposited on its surface, the temperature of the ether is carefully noted and compared with the temperature of the air at the moment by inspecting the thermometer *a*. The greater the reduction of temperature before moisture is deposited upon the ball, the drier is the air ; less and less cold is required to cause a deposition of dew, the more largely the air is charged with moisture. Both balls of the small cryophorus must be carefully freed from air by boiling ether in one of them as in *c* for some time, and then sealing the other, *b*, hermetically, the cold produced by the evaporation of ether poured upon the ball without the thermometer condensing the vapour within so rapidly that ether necessarily evaporates quickly from the other ball. Many varieties of Daniell's hygrometer have been contrived, in which it is used in a more simple and less costly form, as in Jones's hygrometer, and also in Adie's ; different opinions have been expressed as to the comparative accuracy of their indications.

Fig. 323.

2553. 3. In **Leslie's Hygrometer, Fig. 323,** his differential thermometer is used, one of the balls being covered with muslin that it may be easily moistened, and with it the degree of moisture in the air is indicated by the cold produced in the moistened ball, the reduction of temperature being greater and greater, the drier the air at the moment of experimenting, as then the water with which the ball is moistened
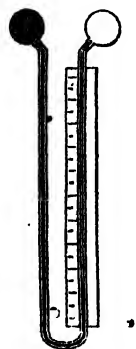
evaporates more and more rapidly. A common thermometer may be used in the same manner for hygrometrical observations.

2554. 4. MASON's HYGROMETER is shewn in the annexed figure 324.   It consists of two thermo-meters as nearly alike as possible, both being covered with white Persian silk, that they may be affected as equally as possible by radiation or currents of air.   One of the thermometers b, is kept continually moistened by water from a small glass tube arranged in the form of a bird-fountain, a few threads leading water continually by capil-lary action to the ball.   But the thermometer a, is never moistened, and accordingly any difference of temperature between them must depend upon the amount of evaporation, and this will take place to a greater and greater extent according to the dryness of the air, producing a propor-tionate reduction of temperature.   The greater the degree of cold, accordingly, the drier is the air to be considered.   When the two thermo-meters indicate the same temperature, then the air may be regarded as saturated with moisture.

Fig. 324.
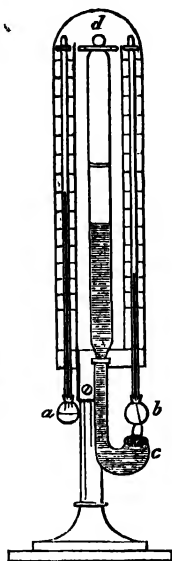
2555. 5. A new hygrometer has lately been constructed, in which the reduction of temperature produced by evaporation in the air is indicated by its action on a pyro-electric arrangement, such as is employed in Melloni's Thermomultiplier.   See Elec-tricity.

2556. From the preceding observations it will be seen, that some hygrometers indicate the condition of the air in respect to moisture, by the change of texture induced in the materials ; while others act by indicating the amount of cold produced by evaporation ; and the third class by shewing the reduction of temperature required for the deposition of dew.

DEPOSITION OF MOISTURE FROM THE AIR.

2557. This depends essentially upon a reduction of tempera-ture, and, as Hutton pointed out, often arises from the inter-mixture of strata of air at different temperatures saturated with

moisture ; the amount of moisture dissolved in the air increasing in a greater ratio than the temperature. When a mean temperature is attained by the intermixture of such strata, part of the moisture is immediately separated.

2558. Again, any portion of air saturated with moisture at the surface of the earth, may often deposit it without being wafted to a colder climate, as when it ascends in the air, the cold attending its expansion as it rises being sufficient to cause its separation.

2559. On the other hand, where moisture may be diffused in the air in the form of a cloud, if that air shall descend in the atmosphere so as to become compressed, its temperature is at the same time elevated, and the cloud disappears, as the matter of the cloud becomes converted into vapour. Hence, in mountainous countries, a stream of warm air from the valleys or from the ocean, transparent and invisible, though saturated with moisture, produces, as it ascends, either rain or a cloud, expanding, and becoming colder as it rises ; but when, according to the progress of the current, it descends again, the cloud disappears.

2560. The term Vesicular Vapour is applied to water in the condition in which it produces a cloud ; it then appears in the form of numerous minute vesicles or bladders, the precise constitution of which is unknown, but they are usually regarded as consisting of extremely thin vesicles of water, like soap-bubbles, and they are also supposed to acquire their buoyancy, or small specific gravity, from being filled with watery vapour. Were they filled with air, they would be too heavy to rise in the atmosphere.

2561. The more irregular the currents in the air in general, the more frequent the fall of rain. But, rain does not fall in largest quantity where it occurs most frequently. The nearer the equator the greater the fall of rain, and the less the number of rainy days. At Grenada, 12° north latitude, the annual fall is 126 inches. In Great Britain, Dr Thomson calculates the annual fall at 32 inches.

2562. The Rain-Gauge, used in estimating the fall of rain, consists of an open funnel, which receives the rain, and by which it is led into a vessel, where its amount is measured. An annual fall of 32 inches accordingly means, that the total amount of rain falling during the year at the place referred to,

would be sufficient to cover the surface of the earth there with water to the depth of 32 inches.

SECT. IV.—IGNITION AND INCANDESCENCE.

2563. All solids and liquids become luminous when subjected to heat, if not previously converted into vapour. This luminousness is independent of combustion. When red-hot, they are said to be in a state of IGNITION; when white-hot, they are said to be INCANDESCENT. A dull red light at first appears, gradually increasing to a bright red, with a tinge of yellow or orange, and terminating ultimately in a pure white light.

2564. In the dark, the luminousness commences at a temperature of 800° or 810°; and a red heat, visible in day light, is usually estimated at 980° or 1000° of Fahrenheit.

GASES, when not in a state of combustion, are not rendered incandescent, nor even brought to a state of ignition, though solids suspended in them instantly become luminous.

2565. The precise cause of ignition or incandescence by the action of heat is unknown. Many attribute it to a species of phosphorescence induced by the high temperature.

SECT. V.—EFFECT OF CALORIC ON CHEMICAL ACTION.

2566. When solids are mingled mechanically together, caloric usually promotes their tendency to combination, if it fuses them, diminishing the cohesion that may have previously operated between the particles of each. On the other hand, it often promotes decomposition when the elasticity of one element is exalted much more by its action than that of the other. It is also considered in numerous cases to exert a specific action.

CHAP. II.—COMMUNICATION OF CALORIC.

2567. Caloric is communicated from one kind of matter to another by CONDUCTION and by RADIATION. Conduction signifies

the slow communication of heat from one particle of matter to another in contact with it; but radiation refers to its rapid progress through a vacuum, through air, and through all other bodies in which its progress is not arrested by the dense aggregation of particles, such as is observed in a mass of iron, stone, and wood, or in ink, milk, or any other similar substance.

2568. Of late, many have adopted the opinion that heat travels precisely in the same manner through a substance in which it is conducted, as when it is radiated from one kind of matter to another through the air; but in the former case, from the numerous obstacles presented to its progress by the frequent opposition of particles, innumerable radiations take place from particle to particle, while in a thin medium, such as the air, or in vacuo, there is little or no opposition to the movement of the air. The light finds a free and unobstructed passage, so that it then darts with incredible velocity in the same manner as light.

Sect. I.—Conduction of Caloric.

2569. Solids are in general the best conductors of heat; liquids come next in order, and lastly gases.

2570. Solids. Metals are the best conductors among solids; then come glass and stony substances; and, lastly, light, spongy, and porous solids, as charcoal, hair, and fur.

2571. Silver and copper are the best metallic conductors, and then, successively, copper, gold, tin, iron, lead, and platinum. Very considerable difference of opinion, however, has been expressed as to the relative conducting power of different solids, and it is not improbable that this may have arisen from the various qualities of the metals used, as the texture of a metal is not only influenced by its state of purity, but greatly also by the mechanical processes to which it may have been subjected, and the density it may have accordingly acquired.

2572. The conducting power of bodies is estimated by the rapidity and the extent to which they are heated, when subjected to the action of a fixed temperature. Or it may be ascertained by the rapidity with which they cool through a given range of temperature under the same circumstances. Count

Rumford found a thermometer which cooled 135° in air in 576 seconds, took the following time when surrounded by the substances mentioned, that being the worst conductor in which the thermometer cooled most slowly.

	No. of Seconds.		No. of Seconds.		No. of Seconds.
Spun Silk,	917	Sheep's Wool,	1118	Eider Down,	1305
Fine Lint	1032	Raw Silk,	1284	Hare's Fur,	1315
Cotton Wool,	1046	Beaver's Fur,	1296		

2573. Ordinary clothing is not essentially warm, but being made of bad conducting materials, it prevents the natural warmth of the body from being quickly abstracted by the air. Furnaces intended to melt glass, fuse metals, and produce very intense heat, are built of bricks and other bad conductors, that the heat within may accumulate there as much as possible. In an ice-house, bad conductors are equally essential, to prevent the external warmth penetrating to the ice. Stoves, however, and apparatus required to give out heat quickly are surrounded with iron, that the heat from within may be withdrawn, and communicated readily to the surrounding air.

2574. Bad conductors, such as glass, are easily broken by comparatively slight alternations of temperature, that part which may be suddenly heated or cooled by direct contact with the warm or cold object, being suddenly expanded or contracted, while the rest of the material within may be left comparatively rigid ; a rent or crack is the necessary consequence.

2575. Liquids, vapours, and gases, from the extreme mobility of their particles, must be considered in a twofold point of view, in reference to the conduction of heat.

I. In these, the heat may travel from one particle to another, the particles themselves being stationary, and the heat may be applied so that there is not necessarily any movement in the particles. Examined in this way, all liquids are found, excepting fluid metals, to be comparatively feeble conductors of heat, as when heat is applied to the top of any fluid.

2576. II. But if, on the other hand, heat be applied to these bodies so that expansion shall take place in the lowest portion, and the dense upper portion shall have an opportunity of descending, then, in this secondary mode, the heat travelling as it

were along with the moving particles, they are found to be good conductors. See pages 663 to 674 inclusive. The illustrations already given under Expansion, Combustion, &c. in the pages referred to, explain this mode of conduction.

2577. Lastly, when a liquid such as water, which is easily evaporated, is placed upon a bright metallic plate at a high temperature, it evaporates with extreme slowness, as a portion of vapour is instantly formed between the liquid and the metal, which prevents their coming into direct contact. The liquid is accordingly supported on the vapour, and floats upon it, continually moving from place to place. But if the temperature be now permitted to decline, the liquid comes in direct contact with the metal, and then evaporates with great rapidity.

Sect. II.—Radiation.

2578. Radiant caloric is supposed to move with the same velocity as light, viz. 192,000 miles per second, and to escape from all radiating surfaces in rays or lines extending at right angles from the body which emits it. It does not affect the air; neither is it affected by the air. A strong current produces no sensible effect upon any caloric that may radiate through it. It is affected variously by solids, which may transmit, absorb, or reflect it in the same manner as light. And as different varieties of heat have been supposed to exist in the same manner as there are different kinds of light, the effect produced by heat falling upon any object may depend upon four circumstances.

1. The kind of heat.
2. The intensity of temperature in the source from which it is derived.
3. The nature of the surface from which it is emitted.
4. The nature of the matter upon which it falls.

2579. Some solids allow heat to pass through them with comparative facility, and are said to be transparent to heat, or DIA-THERMOUS, heat passing through them in the same manner as light moves through transparent bodies. Rock-salt is pre-eminently distinguished in this respect, as it can transmit, when pure, no less than 90 per cent. of radiant heat.

2580. The calorific effect of a body radiating heat diminishes as the square of the distance, and the effect being one at the distance of one foot, it is one-fourth at the distance of two feet, one-ninth at the distance of three feet, &c.

Radiant caloric is refracted and reflected in the same manner as light (see pages 648, &c.), and, as Professor Forbes lately discovered, it may also be polarized.

Bodies that radiate heat powerfully when warm, absorb it powerfully when cold, and exposed to a heating power. The following memoranda will assist the student in understanding many of the more important phenomena of radiant heat.

1. GOOD RADIATORS are good absorbers.
2. BAD RADIATORS are good reflectors.
3. Good reflectors are bad absorbers and bad radiators.
4. Rough and porous bodies are the best radiators and absorbers.
5. Bright and highly polished metals are the best reflectors, and consequently bad radiators and bad absorbers.

2581. The surface of bodies alone has any direct influence on radiation, as was proved by the experiments of Sir John Leslie and Count Rumford. The following table shews the radiating power of different surfaces at the same temperature, according to the experiments of Leslie :—

Surface coated with lamp-black, ...	100
Surface coated with paper, ...	98
Glass, ...	90
Polished metallic surface, ...	12

2582. In experimenting on the subject of radiant heat, Sir John Leslie frequently employed a tin canister maintained at a constant temperature by boiling water, the sides of the canister being coated with lamp-black, paper, glass, and other substances, whose radiating power was to be ascertained. They were then opposed successively to a polished metallic reflector, a differential thermometer being placed in the focus to mark the comparative effect produced by each. The annexed figure (Fig. 325) shews the general mode of operating,

Fig. 325.
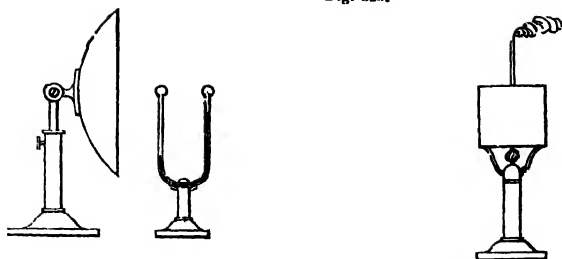
2583. To illustrate generally the radiation and reflection of heat, two reflectors are commonly employed, any warm object being placed in the focus of one, and a thermometer or some other object in the other, to be subjected to the action of the radiant heat. Fig. 326 shews the arrangement adopted, where

Fig. 326.
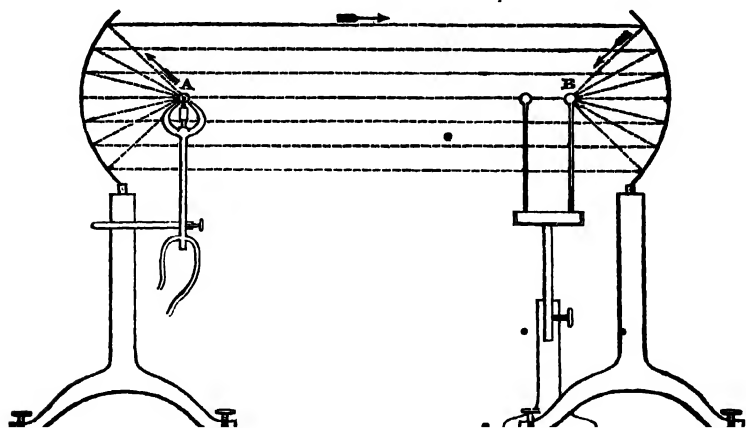
a lime ball A, is employed as the source of heat, being subjected to the action of the oxyhydrogen blowpipe, and a differential thermometer B, placed in the focus of the opposite reflector. The rays of heat emanate on every side from the lime ball; those only are represented which fall upon the reflector in whose focus it is placed, and being reflected from it in parallel rays to the opposite reflector, they are again reflected according to the figure, and condensed in its focus.

2584. In experiments such as these, a large chauffer filled with red-hot charcoal, or a large red-hot iron ball, is generally

employed, but the lime ball I have found preferable, as it can be adjusted with much greater nicety to the focus of the reflectors. The red-hot chauffer or iron ball, is, however, quite sufficient for all ordinary experiments, where the lime ball cannot be procured. With reflectors about 20 inches in diameter, and a lime ball about half an inch in diameter, or a little larger, acted upon by five oxyhydrogen jets, it is easy to kindle inflammable matter placed in the focus of the opposite reflector, though at the distance of seventy or eighty feet.

2585. Hold a bright tin plate opposite a red-hot cinder fire, and then turn it so as to direct the reflected heat and light upon any distant object. Or fix it in a proper position so that the experimenter may go to the distance of a few feet or more and feel the influence of the reflected heat. Then substitute a glass mirror for the tin plate, when the light will be reflected as before, but the heat will be absorbed.

2586. Place the hand in the focus of one reflector, and a very delicate differential thermometer in the focus of the other ; it immediately indicates a rise of temperature.

2587. Place a thermometer in the focus of one reflector, and a mass of ice in that of the other ; the thermometer falls as it radiates heat to the ice.

2588. The phenomena of radiant heat were supposed by Pictet to occur only where there was an inequality of temperature. But they are explained fully more satisfactorily according to the theory of Prevost, that all substances are perpetually radiating towards each other with an intensity proportional to their temperature and the nature of their surface.

2589. In a clear and cloudless sky, radiation takes place to a great extent, and the temperature of the surface of the ground falls proportionally, so that it may be frequently observed very considerably below that of the superincumbent air. The greater the radiating power of the surface of each individual substance, the lower its temperature, and the greater the amount of DEW or hoar-frost deposited upon it, as Dr Wells pointed out. Previously, very vague opinions had been entertained on this point, but Dr Wells shewed that a deposition of dew or hoar-frost does not precede the reduction of temperature observed in good radiators at the surface of the earth and exposed to the open sky, the cold produced by radiation preceding and being the cause of the deposition of dew, &c.

2590. In India, ice is formed in shallow porous cups containing water principally, if not entirely, by the cold produced by radiation, though the temperature of the surrounding atmosphere may not have fallen below 40°.

2591. In cloudy nights, the temperature of the surface of the

Fig. 327.

ground never falls so low as when the sky is cloudless, the radiation from the surface of the ground being then requited by the returning radiation from the clouds. Sir John Leslie's Æthrioscope, Fig. 327, shews in a very marked manner the influence of the clouds in returning radiation. It consists of an extremely delicate differential thermometer, having one ball placed within a hollow metallic case, so that it is entirely excluded from the action of the air, while the other, the upper one, is placed within a brilliantly polished cup. When the latter is exposed to any clear part of the sky, its temperature immediately falls; there is no return to its radiations; but if it be exposed to a clouded part of the sky, the returning radiant heat prevents its temperature from being reduced as in the preceding case.
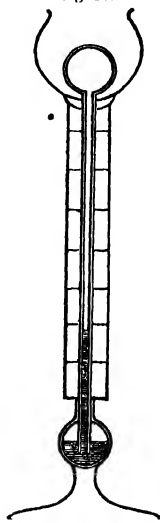
2592. Many familiar instances of the action of radiant heat present themselves to the attentive observer. An open fire, provided with a suitable chimney, communicates heat solely in virtue of its radiant power, all heat communicated by actual contact of the air with the inflammable matter being withdrawn by the column of warm air ascending the chimney. A polished

Fig. 328.
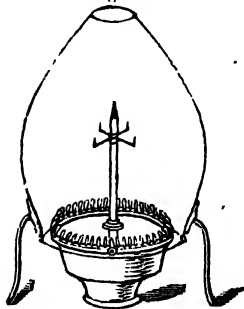
silver or brass wire placed before the fire, does not become warm, reflecting the heat that falls upon it; but, if previously warmed by boiling water poured upon it, it cools slowly, radiating most imperfectly the heat it may have acquired. The annexed Figure (328) represents one of the common roasting gas-burners, the thin lines shewing the form of the large tin reflector placed around it, by which the heat is returned which would otherwise have escaped.

The experiments commonly performed with artificial heat may also be performed with the heat of the sun. By collecting the rays of the sun in a focus with a number of mirrors, the most intense heat is developed. Radiant heat from the sun may also be concentrated by refraction, as in the common burning glass. Bodies radiate precisely in the same manner in all gases, and in vacuo.

2593. A great number of researches have been made in reference to the transmission of radiant heat through glass and other substances since the investigations of Leslie. Delaroche, in particular, has shewn, that the amount of heat which passes through glass is greater and greater the higher the temperature of the body from which the heat is emitted. Melloni has added much to this department of science. He measured with great care the amount of heat intercepted by successive screens, less and less being retained by each succeeding screen, though a very considerable quantity may be intercepted by the first. He has also proved, that the power of bodies in transmitting radiant heat is not necessarily connected with their transparency ; and that, accordingly, a body may be highly powerful in transmitting heat, or *diathermous*, while it may be feebly *diaphanous*, or even not at all capable of transmitting light. Melloni's researches were conducted with his thermo-multiplier, an instrument of extreme sensibility.* See Electricity.

2594. The cooling and the warming of bodies is necessarily influenced, both by the absorbing and radiating power of their surface, and the conducting power of the material of which they are composed. Sir John Leslie and Count Rumford proved, that the cooling of bodies is much more affected by the state of the surface than the conducting power of the materials themselves. The influence of colour on the radiation and absorption of heat is a point that has received considerable attention, but has not been hitherto followed up so minutely as some other branches of

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* Melloni's researches are given in detail in Taylor's Scientific Memoirs.

this subject. The late experiments of Professor Bache tend to prove, that the radiating power is not affected by colour ; but, on the other hand, the power of absorbing heat from the sun's rays is greatly affected by colour. Perhaps much may depend upon the intensity of heat in the source from which it escapes, and the impulse it may consequently receive, the heat of the sun penetrating transparent substances without loss, while terrestrial heat is more or less intercepted. Rock salt is very peculiar in its relations to radiant heat compared with other bodies, transmitting heat from all sources, and of all intensities, with equal facility.

CHAP. III.—SPECIFIC HEAT.

2595. By specific heat is understood the peculiar relation which each substance bears to heat, and, consequently, the comparative quantity required to raise the temperature of each by a given number of degrees. The term CAPACITY for HEAT was originally employed for this purpose, but was not considered so appropriate, as it was supposed to involve a hypothesis as to the nature of heat, and the manner in which it is associated with matter, many arguing that it seemed to be too much in favour of the doctrine of the materiality of heat, whereas, at the present day, the theory of vibrations is more generally adopted. .

2596. The exact manner in which heat exists in matter is unknown, but the amount required to raise the temperature of each body one or more degrees varies much in the same manner as the amount of liquid varies that is required to fill vessels of different diameters to the same height. Thus, if a pound of water, a pound of oil, and a pound of mercury, be taken and heated with extreme caution to the same temperature, it will be found that they absorb very different quantities of heat, the oil requiring much more than the mercury, and the water much more than either. •

2597. According to the experiments of Dulong and Petit, the atoms of elements have the same specific heat ; but this conclusion has been called in question. •

2598. The specific heat of vapours and gaseous fluids is a sub-

ject of very difficult investigation, and extremely varied results have been obtained by different experimenters. All gases and vapours expand as they are relieved from pressure ; their specific heat increases at the same time ; and hence their temperature falls if they be not supplied with caloric from some external source. On the other hand, when gases or vapours are compressed, much heat is suddenly evolved, so that tinder and other inflammable substances may be kindled when subjected to its action.

2599. The specific heat of different substances is much influenced by chemical action, so that sometimes it is increased when cold is produced, though more frequently it is diminished, and then an elevation of temperature is observed.

2600. When a solid is melted, or a liquid converted into vapour, a large quantity of caloric becomes latent, as has been already explained ; and here it is necessary to remark, that the caloric, which is said to become latent, has not always been considered as the cause of the change of form, but rather as being absorbed by the liquid or vapour produced, and thereby preventing any reduction of temperature which might have otherwise arisen from the increased capacity for heat.

2601. Dr Irvine attempted to estimate the absolute zero, on the principle, that the heat in different kinds of matter is proportional to their specific heat ; but the great discordance shewn in the results of different experimenters, has proved that this method is not correct.

CHAP. IV.—DISTRIBUTION OF CALORIC.

2602. The great tendency of heat to an equilibrium, and the extreme rapidity of its movements, lead to the opinion, that an equality of temperature would soon be established over the globe, were this not prevented by the mode in which the sun's rays fall upon the earth, and innumerable phenomena connected with the animal and vegetable kingdom.

2603. The following memoranda connected with temperature ought to be recollected :—

Mean temperature of the air at the surface of the globe varies probably nearly to the extent of . 100° F.

At the equator it is . . . . . 82°.5

At Rome, N. latitude 41°.53, . . . 60°

At Edinburgh, N. latitude 55°.57, . . . 47°

At Melville Island, N. latitude 74°.45, . — 1°.5

And at the pole it has been calculated by Arago, to be — 13°

In insular situations, the extremes of heat and cold are much moderated by the waters of the ocean. .

2604. The LINE of PERPETUAL CONGELATION has a variable altitude in different climates, being higher and higher' as it approaches the equator.

At the equator it is 14,760 feet.

At the Alps, 8,120 ...

In Iceland, 3,084 ...

At the Polar Regions, ice is perpetually observed at the surface of the earth.

2605. The MEAN TEMPERATURE OF THE SURFACE OF THE OCEAN is $32\frac{1}{4}$° in the north seas, and 82° at the equator. At great depths, however, the temperature is much more nearly alike, varying only from 31° in the north seas to 44° at the equator.

2606. Observations in mines, and numerous geological phenomena, have led to the opinion, that the earth was originally a fluid mass at a very elevated temperature, and that probably at the present moment may be, at no great depth from the surface, still in an incandescent state. The conducting power, however, of the mass of the earth's surface is extremely feeble, so that the sun produces a very trifling effect at the depth of 100 feet ; and even at no greater depth than 24 feet, the full effect of the summer's heat does not obtain its maximum till the depth of winter, shewing that six months are required to conduct it from the surface. A little variation is observable, however, in different kinds of strata which vary in their conducting power. In general, the denser it may be, the more rapidly is the caloric conducted.

CHAP. V.—PRODUCTION OF HIGH AND LOW TEMPERATURES.

Section I.

2607. The great sources of heat are the rays of the sun, chemical action, electricity, and magnetism.

2608. RAYS OF THE SUN. If the rays of the sun be concentrated by a lens, or by metallic reflectors brilliantly polished, an intense heat is produced fully equal to that which is developed by any other process.

2609. CHEMICAL ACTION is the great source of heat for artificial purposes, as in the combustion of wood, coal, coal-gas, oil, wax, tallow, and other inflammable substances.*

2610. The precise manner in which heat is liberated during chemical action is not known. The term combustion was formerly applied to those cases where oxygen combined with an inflammable body, but is now applied, in a more extended signification, to all those cases where heat and light are evolved, whether oxygen be present or not, as when sulphur combines with potassium.

2611. MECHANICAL ACTION.—An elevated temperature may easily be produced and sustained for a long time by mechanical action, but this is always accompanied by an increased density in those bodies from which the caloric is evolved, the caloric being as it were mechanically pressed out. If they be again heated in the fire, however, and allowed to cool slowly, or exposed in such a situation that they again recover their original texture, they give out heat a second time when compressed by powerful mechanical action. The development of heat by electricity will be referred to under electricity.

Sect. II.—Low Temperatures.

2612. A reduction of temperature is usually effected in some of the following ways.

* See Carbon, Furnaces and Fire-places, Expansion and Communication of Heat.

1. By PROMOTING RADIATION. The more rough and porous the surface of any substance when exposed to a clear sky, the greater the reduction of temperature by radiation.

2. By REDUCING THE PRESSURE ON GASES OR VAPOURS, their temperature immediately falls, as their capacity or specific heat increases as they expand.

3. By PROMOTING EVAPORATION. Evaporation is always a cooling process to the fluid which evaporates, when the vapour is not produced by the direct communication of heat.

4. By CHEMICAL ACTION. This is the most fruitful source of cold for artificial purposes. The liquefaction of solids is usually resorted to for this purpose, fluidity being induced by the action of solvents. Under ordinary circumstances, the direct application of heat is necessary to render a solid liquid, but when this is effected by other means, part of the heat which maintained the materials formerly at ordinary temperatures is consumed in effecting the change of form, and hence the reduction of temperature. See Freezing Mixtures.

IV. ELECTRICITY.

2613. The term electricity is derived from ηλεκτρον, the Greek for amber. Not long ago, only a few facts were known with respect to this interesting science, which has been so much extended by the researches made in modern times, that it is now known to be intimately connected with all the phenomena of nature and of art. The effects it produces were first noticed in amber, which exhibits, when rubbed, the power of repelling and attracting any light objects, such as a fragment of paper; and a more precise examination of this subject has shewn, that a spark of light appears at the moment of contact, more or less marked according to the previous excitement; and farther, the attractions and repulsions take place according to the following laws :—

I. Bodies similarly electrified repel each other.

II. Bodies in different electric conditions attract one another.

III. Bodies in a state of electric equilibrium neither attract nor repel each other.

See the illustrations with the sealing wax and the feather, immediately before the description of the electrical machine.

2614. The precise nature of electricity is unknown; it is, however, a power of great energy, and exerts an action on all kinds of matter. It is intimately connected with heat and light, which it often developes as intensely as they can be excited by artificial means. It can excite magnetism, and communicates also attractive and repulsive powers to all kinds of matter. Its chemical relations are so extended, that it has been regarded as the real cause of all chemical phenomena. Its influence on the animal and vegetable kingdom is equally conspicuous ; whether we examine the minute phenomena of organic life, or trace its effects on the larger scale, as they are exhibited in the devastating influence of a severe thunder-storm. The subject of electricity did not become an object of general attention, though familiar to the philosophic world, till the experiments of Franklin proved the identity of electricity with the lightning of the thunder-storm.

2615. Electricity cannot be collected by itself like ordinary kinds of matter. It is too subtile and penetrating, and like heat and light tends to diffuse itself among all surrounding objects till an equilibrium has been established. It is usually considered as a fluid consisting of particles repulsive of each other, but attractive of other kinds of matter. Opinion is divided on this point, however, and many regard it as dependent upon vibrations produced in an invisible fluid or ether, the vibrations being of a different kind from those that have been considered to give rise to heat and light.

2616. Electricity, in the language of Franklin, may be termed a simple fluid, and electrical action is induced whenever it is accumulated in excess in one substance, or becomes deficient in others. Where it is in excess, the electric phenomena arise from the electricity leaving the body in which it is accumulated and flowing into surrounding objects ; when it is deficient, they are produced by the electricity moving from all surrounding objects to restore the equilibrium.

'2617. Bodies are said accordingly, in the terms of the Franklinian theory, to be POSITIVELY ELECTRIFIED, when they have

more than surrounding objects ; and NEGATIVELY ELECTRIFIED when they have less.

2618. According to the theory of Dufay, as extended by Symmer, all bodies contain two kinds of electricity, termed vitreous and resinous, these having first been noticed in vitreous and resinous kinds of matters, and the phenomena of electricity depend upon their separation or on their union. On the other hand, when they are combined in proper proportion all electrical phenomena cease. The term vitreous electricity, according to this view, corresponds with the positive electricity of Franklin ; and the resinous with negative electricity. Many of the most eminent electricians have adopted this view of the compound nature of electricity ; but the* hypothesis of Franklin is more simple, and perhaps on the whole, equally consistent with the phenomena presented by electrical action.

2619. EXCITATION OF ELECTRICITY. In general, a body is said to be electrically excited when it tends to communicate electricity to, or to withdraw it from, surrounding objects. For this purpose, an excess of electricity must be conveyed to it, or a portion removed from it beyond what it has in the neutral condition. Bodies may also be excited electrically without gaining or losing electricity, if any process be resorted to by which the portion they may previously have contained is unequally distributed through them. This is effected by opposing to them an excited electric, after supporting them on non-conductors, that their electricity may not be withdrawn.

2620. Electricity is commonly excited by friction, or other varieties of mechanical action, by chemical action, by heat, or by magnetism. When electric excitation arises from the proximity of an excited electric, as explained in the preceding paragraph, it is said to be produced by INDUCTION, and the term Induced Electricity is then applied.

CHAP. I.—COMMUNICATION OF ELECTRICITY.

2621. The term CONDUCTOR, in electrical language, is usually applied to metallic bodies, which are superior to all other sub-

stances in conducting power. The following bodies succeed the metals in this respect, in the order in which they are enumerated :—

1. Charcoal.
2. Acid Liquids.
3. Solutions of Salts.

4. Moist Animal Substances.
5. Water.
6. Gases very much rarefied, or much loaded with moisture.

2622. The term Non-conductor is applied to those substances which have a very weak conducting power, as sulphur, resin, glues, and also dry air, wood, paper, silk, and feathers. The conducting power of bodies is much affected by their condition in reference to heat. Many solids that are imperfect conductors, conduct electricity readily when fused by heat.

2623. When electricity is to be conveyed from one kind of matter to another, they are usually connected by a copper, silver, or other metallic wire. Plates of metal, tin-foil, and mercury, are of great use in adjusting different kinds of apparatus. By dipping the extremity of a copper wire into a solution of nitrate of mercury, and then amalgamating with mercury, a very intimate degree of contact is insured, so necessary in numerous experiments.

2624. The ELECTRIC CIRCUIT is the course which the electricity takes in any electric arrangement, always proceeding from those bodies in which it is accumulated to those in which it is comparatively deficient. Any substance to be subjected to the electric influence must form part of the circuit, so that the ordinary circuit is BROKEN OR INTERRUPTED. If the material which breaks the circuit be a very bad conductor, its conducting power must be improved by moistening it with water, salt, or acid, or in some other way, otherwise the electricity may not pass through it, the circuit being in this case almost entirely interrupted, and then no electrical effects are produced on the subject of experiment.

2625. Electricity appears to spread over the surface of bodies, rather than to penetrate into the interior. This statement, however, must be taken with great limitations, as every particle of matter has a peculiar relation to the electric fluid, and is associated with a portion of it, which may be more or less easily detached from it. Pointed conductors are more powerful in with-

drawing electricity than those that are globular. They also discharge it rapidly from bodies in which it is accumulated. If it be required to discharge much electricity at once, then a ball is preferred to a point.

Fig. 329.
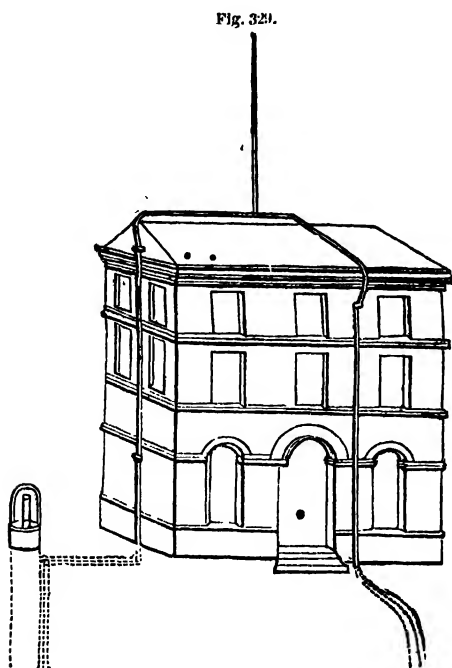
2626. When a house or large building is to be defended from the action of the electric fluid, it is usually surmounted with a pointed conductor placed in the most exposed situation ; this conductor, or LIGHTNING ROD, being led down by one or more branches, according to the size of the building, and terminating deep in moist earth, or, where it is possible, in a well, as in the manner represented in the annexed Figure (329).

2627. In the same manner, on board ship, the electric fluid is usually guarded against by a metallic chain led from the topmast into the water, as shewn in the annexed Figure (330).   Instead of a chain, a rope made of many small copper wires has been proposed by Mr Roberts, which has the advantage of being flexible, while it also insures a more perfect continuity of metal.

It may be attached in the mode shewn by the dotted line, instead of following the course represented by the chain. The conducting metallic rope may be easily protected from the action of the air, but it would not be so easy to prevent the links of the chain from oxidation. Instead of merely leading the metallic rope or chain to the water, it is sometimes fixed into the copper sheathing of large vessels.

2628. An excited electric, supported on a stool with glass feet, or on any other very bad conductor, is said to be INSULATED, as it cannot then either communicate electricity readily to the earth, or receive electricity from it, if the air be dry.

Fig. 330.
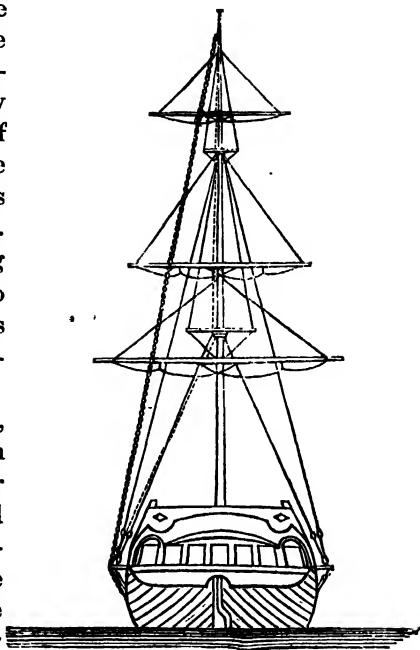
CHAP. II.—ELECTRICAL MACHINE, LEYDEN JAR, &c.

2629. In the common electrical machine, electricity is developed by friction. If glass, sealing wax, or amber, be rubbed with a silk or woollen cloth, the rubber assumes one electrical condition, and the glass or other substance passes to a different state. The condition of the surface, and the peculiar nature of the substance used as a rubber, modify the result. Smooth glass is rendered positive by a woollen cloth, but rough glass becomes negative with the same substance ; and sealing-wax is rendered positive by metallic substances, but negative by hare's skin.

2630. ELECTRICS are bad conductors ; and electrical pheno-

mena are induced in them with great facility.   Good conductors
are called NON-ELECTRICS, as they are with difficulty rendered
electrical unless insulated.

2631. When any electric has been excited by friction, if a
feather be applied to it, it first receives a portion and is then
repelled, after it has attained the same electric condition, as the
body to which it is approached.   The individual fibres of the fea-
ther also repel each other, in the manner repesented in the

following figure, which shews
the feather at the moment it is
passing from a large stick of
sealing-wax by which it is repell-
ed.   In a short time the feather•
loses electricity, which is with-
drawn by the air, returning
again to its natural condition.
It is now again attracted when
approached to the sealing-wax ;
and this may be repeated many
successive times.   Hence, then,
an excited electric may retain
its electricity when surrounded
by a dry atmosphere, for a con-
siderable period.   But, if the
hand be drawn over the wax, or
a pointed wire be applied to
different parts, the electricity
may be quickly and entirely re-
moved.   Accordingly, in con-
structing an electrical machine,
the great object is to produce
electricity in the first instance,
and then to remove it where it
can be conveniently accumulat-

Fig. 331.

ed ; that part of the apparatus in which it is first accumulated is
usually termed the PRIME CONDUCTOR.

2632. Two kinds- of electrical machines, are commonly de
scribed, viz. the cylinder and the plate machines.   In the com-
mon cylinder machine, the electricity is produced by the friction
of a hair cushion and a piece of silk, with a cylinder of glass,
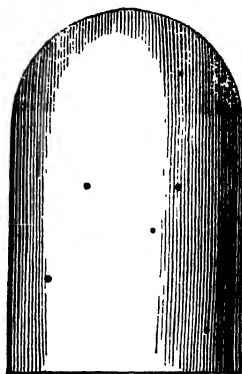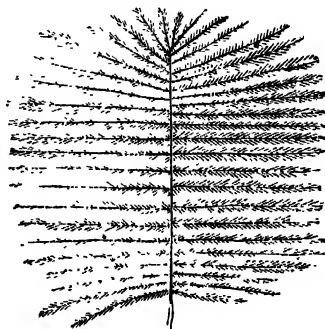
which is made to revolve rapidly : pointed brass wires remove the electricity to a large cylinder or ball, made of sheet-brass, in which it is accumulated. It is insulated by a glass-support. Were it not insulated, the electricity communicated to it would pass at once to the earth. The rubber must be connected with the ground by a chain or other good conductor, to supply electricity to the machine as it is exhausted, otherwise it soon ceases to be produced ; the rubber and the chain are generally connected in the cylinder machine by a conductor, which has been termed the RUBBER'S CONDUCTOR, similar in its form to the prime conductor. The annexed figures represent a section and a ground plan of the cylinder electrical machine, with the position of the prime conductor, and an attached Leyden jar.

Fig. 332.
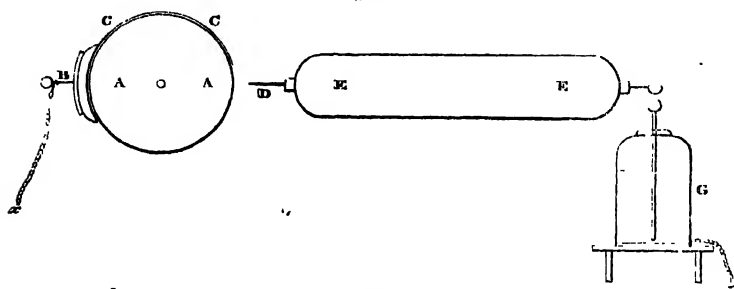
Fig. 333.
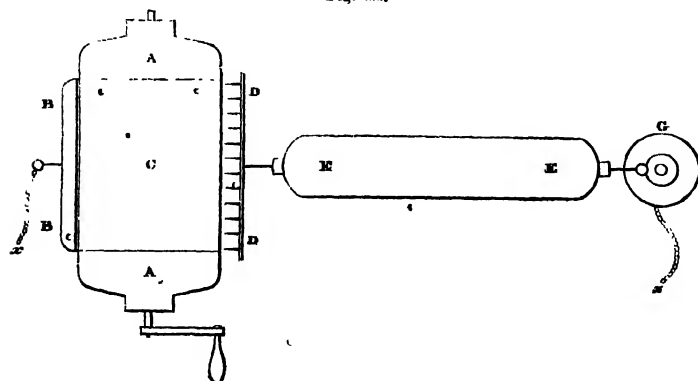
2633. The letters refer to both figures. A A A A the cylinder, B B B the hair cushion, *x*, the chain and ball by which the cylinder is supplied with electricity from the ground, or from the rubber's conductor which communicates with the ground. C C

the silk proceeding from the hair-cushion attached to **B, D D D** the pointed wires leading off the electricity from the machine to the prime conductor **E E E E, G G** the Leyden jar supported on a stool with glass feet, the exterior coating being connected with the ground by a chain when it is required to charge the jar.

Fig. 334.

Fig. 335.

Fig. 336.
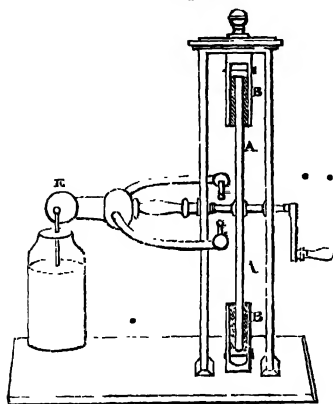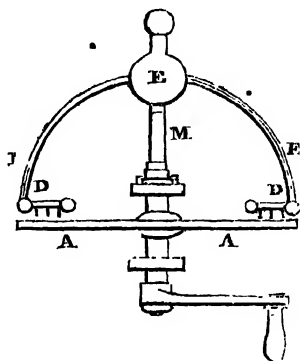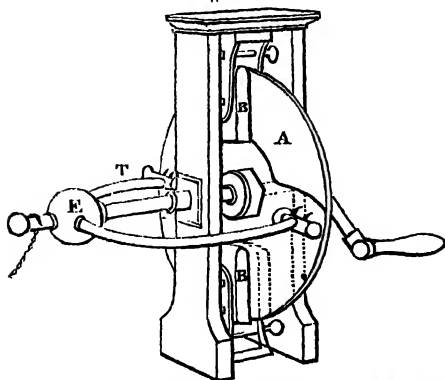
2634. In the three annexed figures, a horizontal section and two perspective views of the plate electrical machine are given ; A A A A A shew the glass plate used as a substitute for the cylinder, B B B B the hair-cushions from which the silk proceeds ; D D small brass points which receive the electricity ; E E E E the prime conductor, M the glass support by which the prime conductor is insulated from the rest of the machine.

2635. In the plate electrical machine, no chain is required to communicate with the ground, as the frame work that supports the plate establishes a sufficient communication with the earth, and may be considered as performing the same office as the chain in the common electrical machine.

2636. The frame of the plate machine should always be placed where it may draw electricity from the ground, and, like the chain x, of the cylinder electrical machine, it may be attached to a gas or water pipe, when this can be conveniently done, as it insures perfect contact with a good conducting medium.

2637. The hair cushion is usually covered with an amalgam, which may be made with two parts of mercury, one of zinc, and one of tin. The amalgam should be spread freely upon the cushion, as it is very powerful in promoting the action of the machine, partly by the more perfect contact which it insures between the cushion and the glass, and partly by the oxidation of the amalgamated metals. This view has been much strengthened by the circumstance, that little or no electricity is developed, according to some statements, when the electrical machine is worked in an atmosphere of carbonic acid gas. Some have even imagined that without chemical action, directly or indirectly, no electricity can be developed; but this opinion is not generally supported.

2638. In working the electrical machine, it cannot be kept too dry, or too carefully preserved from dust. The prime conductor must always be thoroughly insulated, supporting it on glass feet ; and in the common cylinder machine, the cylinder must also be supported on non-conductors.

2639. In damp weather, the machine should be carefully heated, and the whole maintained at a uniform temperature. Small chauffers, containing a few pieces of charcoal, are very convenient for this purpose. A high temperature should be cautiously avoided ; the glass is apt to be broken by the incautious application of heat ; moreover, very hot air conducts electricity away rapidly, producing great loss of power.

THE LEYDEN JAR.

2640. THE LEYDEN JAR was so named, as it was invented at Leyden. It is a glass jar or bottle coated externally and internally to within a few inches of the top with tinfoil, a rod with a ball at the top passing through the cork and communicating by a chain with the internal coating. Electricity conveyed from the prime conductor to the ball, is led by the rod and metallic coating to the interior of the jar ; a corresponding quantity is expelled from the exterior in consequence of induction, and when one ball of the discharger touches the exterior of the jar,

and the other is approached to the ball of the brass rod, the electricity passes as a powerful spark from the interior to the exterior, and the equilibrium is restored.

2641. Fig. 337 represents the common form of the discharger, consisting of a bent brass rod terminating in two balls, the rod being attached to a glass handle.
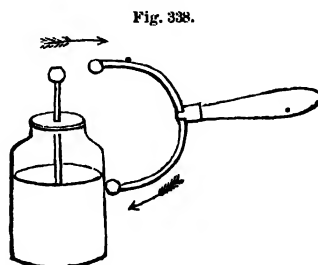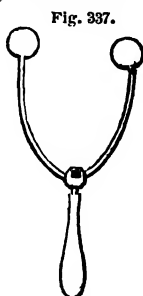
Fig. 337.

Fig. 338.

2642. Fig. 338 shews the discharger in use, one ball being applied to the outside coating of the Leyden jar, the other to the ball of the jar, when the electricity follows the course indicated by the arrows.

2643. To illustrate more precisely the nature of the Leyden jar, let a in the annexed figure (Fig. 339) represent the prime conductor of an electrical machine; b the ball of the Leyden jar leading to an internal moveable metallic coating in the interior of the jar; ff the glass, and d an external moveable coating; e the metallic chain; the ball b being supported on a long glass handle, fixed into o. If the jar be now charged in the usual manner, it may then be discharged as represented in the annexed figure (Fig. 340).

Fig. 339.
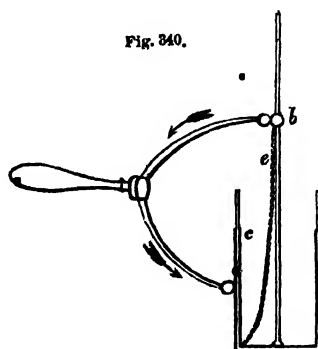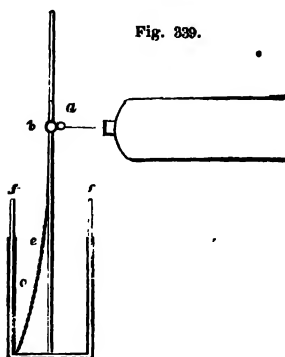
Fig. 340.

Let it now be again charged, and then the coating *o* may be re-moved by the long glass handle ; the glass *ff* may also be lifted out of the external coating *d*, so that they shall all be separate as shewn in Figs. 341, 342, 343. But all this time the electricity is lodged on the glass, the coatings having mere-ly been instrumental in conveying it to the glass ; and on re-placing the coatings, an electric spark may be obtained by discharging it in the usual manner, without any fresh charge.
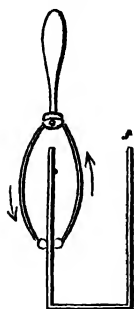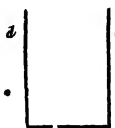
Fig. 341.

Fig. 342.

Fig. 343.

2644. If, before the coatings be replaced, the discharger be connected with the exterior and interior of the jar, in the manner shewn in Fig. 342, a minute quantity of electricity may be conveyed from the interior to the exterior of the jar ; and by touching every part successively, at last the whole might be discharged. But this would be a tedious process, whereas the metallic coatings allow the whole to be discharged at once.

2645. The Leyden jar cannot be charged, unless electricity be conveyed from the exterior at the same time that electricity is conveyed to the interior from the prime conductor of the electrical machine ; accordingly, if it be supported on dry glass, or on a glass footstool, in the manner shewn in the figure of the cylinder electrical machine, or on any other very bad conductor, as a silk-handkerchief, or a sheet of brown paper, it either receives no electricity at all, or a very imperfect charge, unless a chain be attached to the outer coating and led over the bad conductor to the ground. ·

2646. When the interior coatings of a number of jars are connected by metallic contact with each other, the jars being placed in a box and the exterior coatings connected in the same manner. they may be all discharged as one jar. The annexed, Fig. 344, illustrates the

Fig. 344.
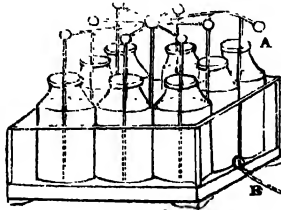
above arrangement, and is usually termed the electric battery. A and B are the points to be connected by the discharger.

2647. The same precautions must be adopted, in using the Leyden jar, that have been described in regard to the electrical machine. Dust, excessive heat, and moisture, must be equally avoided.

2648. Jars have also been constructed of a fixed size, and placed at a determinate distance from a larger jar, so that they may be filled successively any given number of times, and their contents then transferred to this second jar, discharging themselves always into it when they have received a definite quantity of electricity. They have been termed UNIT JARS by Mr Harris, who introduced them.

ELECTROPHORUS.

2649. The electrophorus is a small electrical apparatus, which is quite sufficient for performing experiments when a very feeble electric spark is all that is necessary. It consists of a resinous cake, and of a cover a little less in diameter than the cake. When once excited, it may be retained in action for months, and sometimes even for years; the cake not communicating electricity directly to the cover, but rather inducing, in the side that touches it, an opposite electric condition, in the same manner as in the condenser, an instrument to be immediately described.

2650. The resinous cake is prepared by melting together equal weights of common resin, shellac, and Venice turpentine, and pouring the compound while still hot upon a metallic plate, or into a circular dish of tinned iron. It should be struck lightly with a piece of folded warm flannel, or a fox's tail, when required for use. The cover, which is usually made of a piece of thin wood covered with tin-foil, or of a plate of brass, and provided with a glass handle, is to be placed upon the resinous cake, touched with the finger while in this position, and removed by the glass handle. It is now excited electrically; and, on bringing any substance near it, a spark is given off, which may be transmitted through a gaseous mixture, or any other
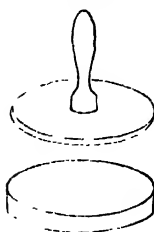
Fig. 315.

substance to be subjected to its action. Many inflammable gases mixed with oxygen in the proper proportion may be analyzed in this manner, the quantity of the resulting products indicating their composition. For this purpose, Volta's or Ure's eudiometer is generally employed. In using either of them the temperature and state of the barometer must be attended to.

2651. To increase the power of a feeble spark, the CONDENSER (Fig. 346), an instrument introduced by Volta, is much employed. It consists essentially of two discs of metal, one being fixed firmly upon an upright glass-support, while the other may be either directly opposed to it, or drawn back in the manner represented by the dotted line, its support, which is metallic, moving upon a joint placed immediately above the stand on which it rests. If the insulated disc be electrified by the approach of an excited electric, it immediately attracts a portion of electricity ; and the other disc being then opposed to it, the charge communicated to the first affects the other by induction. Part of the electricity of the latter is repelled ; and, being in different electric conditions, they tend to sustain each other's peculiar electric excitement. More electricity may accordingly be now communicated as at first to the insulated plate ; and, by repeated contact with the excited electric, at last the charge becomes much stronger, producing indications, when B is withdrawn, and effecting actions, which it was unable to do at first.
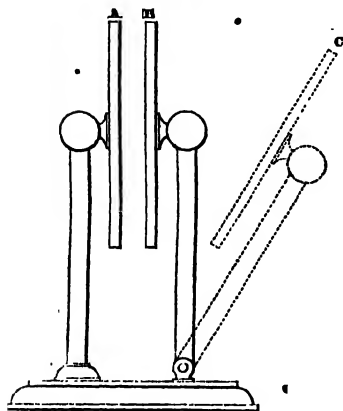
Fig. 346.

Experiments with Electricity excited by Friction.

2652. Excite positively any body, as *a*, Fig. 347, by connecting it with the prime conductor of the electrical machine, and oppose to it a long tube of varnished tinned iron *b b*, insulating it from the ground by

Fig. 347.

supporting it on glass feet.   The tube immediately becomes excited unequally by induction, the extremity next the positively excited electric becoming negatively, and the other end positively electrical.   If small pith balls be suspended from each end, and from the middle, they are found to repel each other at either extremity, but to be neutral in the middle.

2653. Hold a piece of pith suspended by a long silk thread opposite the prime conductor of the electrical machine.   It is immediately attracted, and then repelled in the same manner as in the experiment with the wax and the feather.   See paragraph 2631.

2654. Connect with one extremity of the prime conductor,
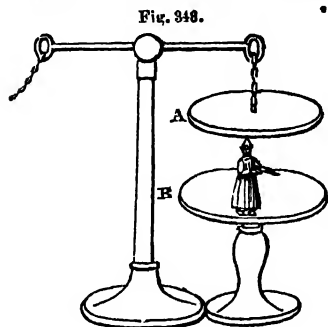
Fig. 348.

properly excited, a metallic rod insulated upon a glass pillar, and suspending a thin disc of brass or copper, in the manner seen in Fig. 348. If another disc connected with the ground be then placed below it, a fragment of thin copper leaf, or any light substance, as a figure, may be sustained continuously dancing or suspended between the discs, communicating electricity as rapidly to the lower one as it receives it from the upper disc, so long as the electric excitation is continued.

2655. ELECTROSCOPES are instruments intended to indicate electric excitation, and the peculiar condition of electric excitement.   ELECTROMETERS are intended more specifically to measure the amount of electric excitement.   At present, however, both terms are in general used indifferently in regard to instruments for indicating the presence of electricity, without reference to the specific quantity.

Fig. 349.

2656. BENNET'S GOLDLEAF ELECTROMETER, Fig. 349, consists of two delicate gold leaves suspended from a brass cap, insulated by the glass vessel that supports the cap. It is very delicate in its indications, and when a glass rod is brought near it after being excited by rubbing, it immediately causes the leaves to diverge, repelling
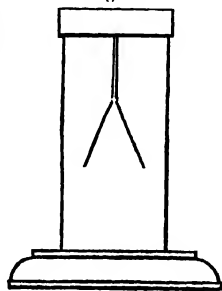
each other as they are similarly electrified. If a stick of sealing-wax be excited and brought near the electrometer, the opposite electric condition of the excited wax, neutralizes the excitement already produced by the glass. Hence the nature of the electric excitement produced in any body is indicated by the effect produced by another excited electric whose condition is known, as it increases the divergence of the leaves if it be of the same quality, but diminishes it when the reverse is the case. This electrometer must be very carefully used; when the electricity is in large quantity in any body, and too closely approached to it, the leaves are apt to be torn.

2657. The QUADRANT ELECTROMETER is a much less delicate instrument usually attached to the prime conductor of the electrical machine; it is then lifted out of the stand represented below it, and transferred to an aperture in the conductor made for its reception. The moveable pith ball, suspended from the brass rod which supports the electrometer, is repelled to a greater and greater distance the more powerfully the electrical machine is in action, and, accordingly, by examining the point where the fibre by which it is attached cuts the graduated arc, the degree of excitation in the machine is indicated.

Fig. 350.
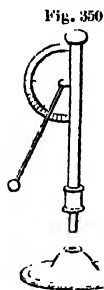
2658. The TORSION ELECTROMETER of COULOMB is a very delicate instrument. It consists essentially of a very small needle of shell-lac suspended horizontally by an extremely slender silver wire, or by a fibre of silk as spun by the silk-worm, the support *d*, from which it depends, being insulated by the glass vessel on which it rests, and which serves as a protection at the same time to the instrument from the action of air, dust, and moisture. Each extremity of the needle is terminated by a small gilded pith ball, one of them being in contact with the ball of the metallic conductor *c b*, which passes through an aperture in the glass case. When an excited body is made to touch *c*, the pith ball in contact with it assuming the same electric condition, is instantly repelled to an extent proportional to the degree of excitement; and when the electricity is withdrawn, the torsion of the suspending thread causes the needle

Fig. 351.
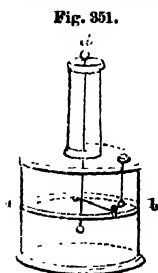
again to come in contact with the conductor at *b*. The graduated arc *a b* serves to measure the amount of the torsion.

2659. The student should now perform a number of experiments with the different electrometers, so as to become familiar with their mode of action, opposing them successively to various bodies differently electrified, to the prime conductor of the electrical machine, or to other bodies electrified by it.

Fig. 352.

2660. If a ball connected with the prime conductor of an electrical machine, be made to electrify another ball, terminating in a bottomless glass jar, in the manner represented in the figure (Fig. 352), it communicates electricity quickly to the interior of the jar; and if a number of pith balls be put within the jar where it rests, the pith balls are attracted by the interior of the glass, and repelled whenever they acquire the same electric condition. The repelled ball is again attracted and repelled as at first, till the whole of the electricity is withdrawn from the interior of the jar.
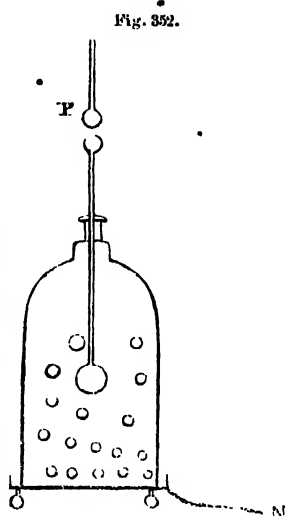
2661. When an electric spark is to be passed through a fine wire, it may be stretched as represented in Fig. 353. The wire is fixed at the top of the two supports R S and C S; R and C being placed near each other when the wire is first fixed, but separated gradually afterwards, until the wire is stretched, both moving upon the screw N to which they are attached. By approaching the discharger D, to the prime conductor B, the electricity passes through D, and along the wire W to R S; the glass support SC preventing it from passing in that direction.

Fig. 353.

2662. Electricity proceeds with extreme velocity not only through the atmosphere like light and heat, but also through
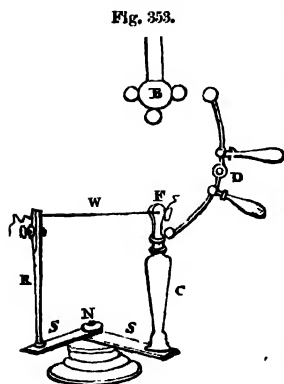
solid metallic conductors; and even when they are composed of
many fragments merely touching each other, still an extreme
rapidity of progress may be observed. Thus, if an iron chain
containing many thousand links be suspended in the air, one ex-
tremity being brought in contact with the outside coating of a
Leyden jar, while the other is attached to a discharger, so that
in discharging the jar the electricity may be made to pass
through all these links successively, still so rapid is the move-
ment that every one appears luminous at the same instant, a
small portion of iron being abraded from each link, which burns
with corruscations as it acts upon the air.

Fig. 354.
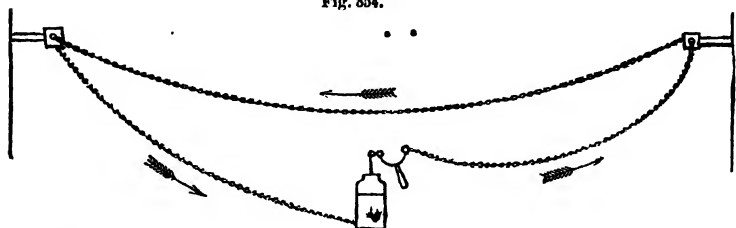
2663. By passing the electricity through substances less per-
fect in their conducting power, its motion is retarded, and then

Fig. 355.
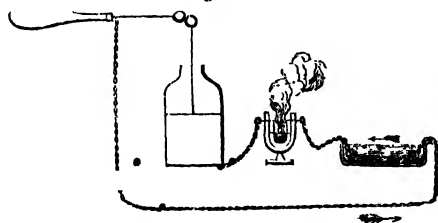
it may be made to inflame
gunpowder, and other sub-
stances which are not usu-
ally kindled with facility.
Fig. 355 shews an arrange-
ment by which a small por-
tion of gunpowder may be
deflagrated, when the elec-
tricity is discharged through water.

Fig. 356.
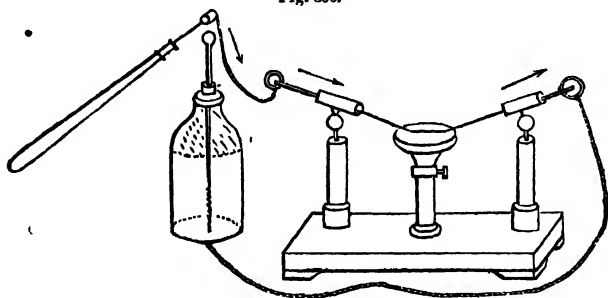
2664. The UNIVERSAL DISCHARGER consists of two rods, which are usually connected with chains made to communicate with the external and internal coatings of the Leyden jar, and made to rest upon a moveable support, on which can be placed any matter to be subjected to the action of the electric fluid—the extremities of the wires touching it on either side. In Fig. 356, they are represented as attached to an exceedingly delicate metallic wire, through which the electricity is to be passed ;—unless the wire be very fine, the electricity will pass through it without dissipating it.

2665. Place successively in the same manner, a piece of white sugar about an inch in diameter, a little fulminating mercury, half a grain of fulminating silver, and pass through each a powerful charge from the Leyden jar. The sugar becomes phosphorescent ; the fulminating mercury is sometimes inflamed, but occasionally dissipated without combustion ; the fulminating silver detonates violently. In the same manner, a thin slip of gold-leaf pasted on a card may be dissipated by the electric fluid, a card interposed between the wires is pierced, and an aperture left. If the electric spark be passed through the finger, a bright blood-red light is seen ; the finger appearing transparent. By transmitting it through powdered resin diffused through cotton, the resin is inflamed. When the beginner has not a discharger of the above construction, he may with great facility in general construct a temporary discharger with a few pieces of chain and copper wire ; one, such as is represented in the annexed figure 357 does very well. Two wires attached to two retort stands conducting the electricity through the matter subjected to experiment. The retort-stands should be placed upon glass, very dry brown paper, or some other non-conducting material, that they may convey no electricity through the table on which they rest.
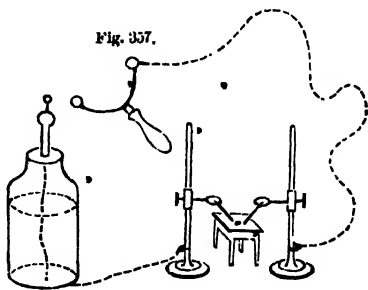
Fig. 357.

2666. Volta's eudiometer (Fig. 358) is made of a stout glass tube with two platinum wires fixed into it near the top where

Fig. 358

it is closed, and approaching till they are at a very little distance from each other within it, about a quarter of an inch. The mixture to be detonated is then introduced into the eudiometer over water or mercury, as may be necessary, keeping it in an upright position, and wiping the upper part with a cloth to remove any adhering water or mercury ; on connecting one of the wires with the ground by a chain, or touching it with the finger, and bringing the tube near the conductor after it has been properly charged, an electric spark will be immediately transmitted through the mixture, passing between the terminations of the wires within the tube, and causing it to explode.

Fig. 359.
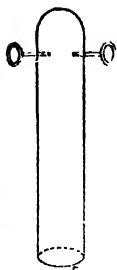
One of the wires should terminate in a brass ball without the eudiometer, that a larger spark may be drawn from the conductor than can be obtained with the wire alone.

2667. A small part only of the eudiometer tube should be filled with the mixture to be exploded ; the figure 359 illustrates the manner in which the spark is transmitted.
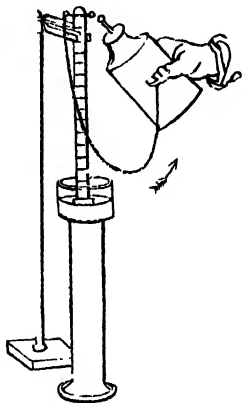
2668. Dr Ure's eudiometer (Fig. 360) is more convenient than Volta's for detonating small quantities of inflammable mixtures by means of the electric spark. It consists of a bent tube, closed at one end, with wires fixed into it in the usual manner ; the mixture is introduced after filling it with mercury, and then the greater portion of the liquid still remaining in the open extremity of the tube is poured out ; after this it is placed in the position represented in the cut. The open end is now closed with the thumb, which is placed so as to touch one of the balls ; the electric spark may now be applied to the other end. The gaseous mixture at the top expands as the spark passes through it, and presses upon the mercury below, forcing a portion of it into the other extremity of the tube, where the air acts as a spring, and moderates the violence of the explosion. It is necessary to leave as much mercury in the open

Fig. 360
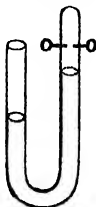
extremity as will completely fill the other, should a complete condensation accompany the detonation.

2669. The electricity of the electrical machine is of great intensity, though the quantity developed may be exceedingly small. The experiments of Wollaston, Pouillet, De la Rive, and Faraday, have shewn that though it presents peculiarities, still it is essentially the same with electricity developed by other processes, an opinion which was not formerly considered to have been satisfactorily demonstrated. When required to produce chemical effects, its progress in the electric circuit should be retarded in the manner recommended by Faraday, by causing it pass through a long moistened string. A mixture of iodide of potassium and moistened starch forms one of the most delicate reagents for indicating the chemical action of the electricity of the electrical machine, iodine being liberated, and immediately acting upon the starch, when the usual blue tint appears.

Of the Electric Shock.

2670. The effect produced upon the system by the electric fluid varies exceedingly according to the manner in which it is communicated, the source from which it is derived and the quantity brought into action. In the lightning of the thunderstorm it appears in its severest form, producing, too frequently, instantaneous death; and in a milder form, it is often the cause of some of those varied sensations which are attributed in many instances to the state of the weather, the air on some occasions conveying electricity to the body, while at other times the living frame is positive in reference to the air, and communicates electricity to it. The following illustrations will enable the beginner to become familiar with the arrangements adopted in communicating electricity from the prime conductor of the electrical machine, or from the Leyden jar. He cannot too particularly recollect, that wherever the electricity is to be passed, that part of the body must form part of the circuit, and be interposed accordingly between the prime conductor and the ground, or between the interior and exterior of the Leyden jar.

2671. In Fig. 361, the electricity passes from the prime con-

Fig. 461.

ductor of the electrical machine
to the right hand by a chain, and
would be instantly conveyed
through the body to the ground,
were the glass feet of the elec-
trical stool not interposed, which,
from their non-conducting pow-
er, allow the electricity to accu-
mulate in the system.   Any in-
dividual, accordingly, standing
in the manner represented, may be considered as an extension
of the prime conductor, loaded with electricity according to the
power of the machine and the state of the atmosphere, so that
if another person approach him, he may take an electric spark
from his knuckle, from his shoulder, from his head, from his
foot, and indeed from any part of the body.   If he shall now,
however, descend from the electric stool, and stand on the
ground, the electricity passing quickly to the earth, no spark
can be obtained from any part of the body.

2672. If a small cup containing sulphuric ether, and resting

Fig. 362.

on a metallic support, as in Fig.
362, be held in the hand, by any
individual standing on the ground,
while another insulated on the
electric stool, and holding the
chain in one hand, places the
forefinger of the other over the
ether, the electricity escaping
through the ether generally in-
flames it.
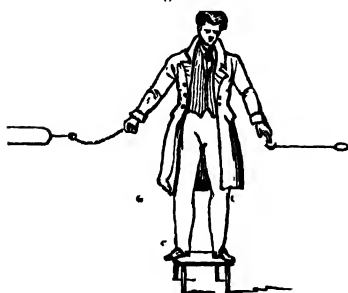
2673. The amount of electricity required to charge different
individuals, so that a spark of the same size shall be obtained
from each, is exceedingly various.   The nature of the clothing,
the texture of the hair, and in particular the dryness of the boots
and shoes that may be worn, should the experiment be tried in
rainy weather, affect much the result.   But, independent of all
these, there appears to be as good reason for believing that dif-
ferent persons have different capacities for electricity, and that
they vary in their conducting power, as that they are affected in
very different degrees by a shock of the same intensity, accord-

ing to their age, peculiarity of constitution, and mode and habit of life.

2674. In Fig. 363, the arrangement is shewn that is adopted when the electricity is passed through the head ; if the hand of

Fig. 363.

each of those in the circuit be placed upon the forehead of the next individual, the electricity is conveyed more effectively than when it is allowed to rest on the hair of the head. In trying this experiment, the Leyden jar should be charged at first so feebly as to produce a spark barely visible in daylight, gradually and cautiously increasing the amount in successive trials, as a very strong shock given in this manner might prove injurious. In discharging the Leyden jar, so as to give a shock to a number of persons at the same time, they must all touch each other, while one at one extremity lays hold of a chain in communication with the Leyden jar, the other touching the ball of the Leyden jar with a metallic rod also terminating in a ball. The electricity passes in the manner indicated by the arrows.

2675. Fig. 364 shews the usual manner adopted in giving a
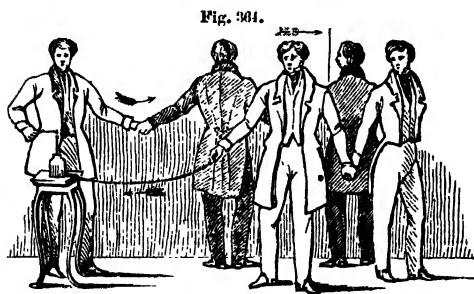
Fig. 364.

shock to a number of persons at once, all joining hands so as to form a continuous connection as in the preceding instance, while those at the extremity hold the rod and chain in the usual manner.

2676. Fig. 365 illustrates the manner in which electricity may be passed from the elbow to the wrist by the Leyden jar, without affecting any other part of the body.

Fig. 366 shews the arrangement adopted when SPONGE POINTS are used, whether in transmitting the electricity of the electrical machine, or of any other apparatus.

3 A
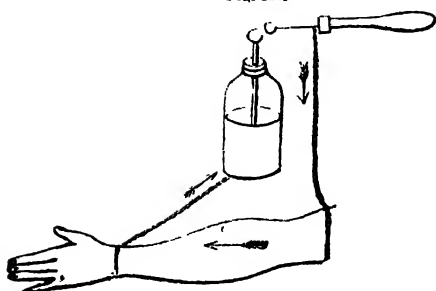
Fig. 365.

Fig. 366.
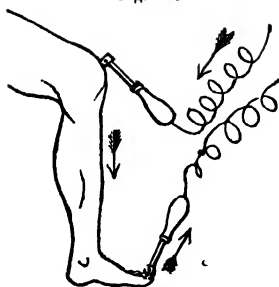
2677. These sponge points are merely small portions of sponge, generally moistened with common salt, which may be slightly acidulated if a still greater conducting power be required in operation with galvanic or magnetic electricity. They are made to communicate directly with the chain and ball of the Leyden jar, or with the positive and negative poles of any other electric apparatus, and accordingly any invalid may hold the non-conducting handle in his own hands, and direct the application of the electric fluid as he may prefer, while an assistant makes the necessary connections. The wire passes through the nonconducting handle to the sponge.

CHAP. III.—GALVANISM.

2678. GALVANISM or VOLTAISM are the terms usually applied to electricity developed by chemical action, from Galvani and Volta, the earliest cultivators of this branch of the subject. Galvani shewed that contractions are excited in the limbs of a frog when a zinc and silver plate are placed, the one upon the nerve and the other upon the muscles, and then made to touch each other; he considered that the electricity was present in the muscles, and merely conducted by the metals. But Volta supposed that the effect was due to the contact of the metals, and soon afterwards constructed the VOLTAIC PILE, which is similar in its general arrangement to the trough now in use.

2679. The liquids used to connect the metallic plates are not now regarded as conductors merely, they are the real source of electricity during their action upon the metals. Davy's opinion was, that the first action commences by the contact of the

GALVANIC BATTERY.

2683. It is much more frequently used than the electrical machine for chemical purposes; and, though a variety of improvements have been made of late in the method of constructing apparatus of this kind, perhaps there is still no modification of it so generally resorted to as the galvanic trough, in which the plates are arranged in the manner proposed by Cruickshanks. There are few experiments which cannot be performed with 120 plates, each about four or six inches square, charged with acid liquor of different strength according to the purpose for which it may be required. For ordinary experiments, a mixture of 2 parts by measure of sulphuric acid, 1 of nitric acid, and 80 of water may be employed; but when it is necessary to produce great heat and light, 1 part by measure of sulphuric acid may be mixed with 3 of nitric acid, and 60 of water; and a still smaller quantity of water may be occasionally employed. Even concentrated nitric acid is sometimes used in particular cases, where a momentary effect of great intensity is required. To examine its nature we must first attend to the action of a plate of zinc with one of copper in an acid liquid.

2684. When a single pair of plates is employed, the copper is always the positive pole (if an acid liquor be used) the electric current flowing in the manner represented in Fig. 369, viz. from the zinc to the copper through the liquid, and from the copper to the zinc when the wires between the two plates are connected together.

Fig. 369.
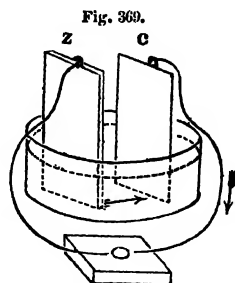
2685. In compound galvanic arrangements the extremity of the battery terminating with the plate of zinc becomes the positive pole; here, however, it must not be forgotten that this depends solely on the arrangement of the plates; for, as is represented in the figure of Cruickshanks's trough, Fig. 370, the electric fluid moves from the zinc through the liquid to the copper, as in the preceding case, and the zinc and the copper-plates at the extremities of the battery do not contribute in any degree to

Fig. 370.
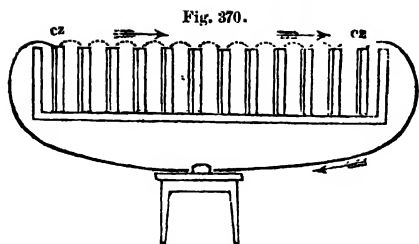
the action, and might be removed altogether without in any degree affecting it. No difficulty can be experienced by the student in understanding why the zinc extremity of the battery should be the positive pole in a compound galvanic arrangement ; if he look on a galvanic trough of the usual construction, he must perceive that it is not by the mutual action of the plates that are soldered together and the liquid on either side that the galvanic electricity is produced, but that it is developed by the action of the liquid on the plates between which it is interposed ; these are represented as connected together by the dotted lines in the figure, and the plates at the extremity may be considered merely as a part of the connecting wires.

2686. Formerly, however, the electricity of the galvanic pile or trough was supposed to be produced by the contact of the metals, and conducted by the liquid interposed, and hence the plates were fitted up in pairs, a practice which has still been continued, though a very different view has been adopted as to the origin of the electricity. The following view shewing the active pairs of plates according to the theory of contact, and the chemical theory will explain some of the apparently contradictory statements that are so frequently made as to the nature of the plates terminating any galvanic arrangement.

According to Volta's theory of contact,

1st Pair.	2d Pair.	3d Pair.
Copper, zinc, liquid.	Copper, zinc, liquid.	Copper, zinc, liquid.

According to the chemical theory,

1st Pair.	2d Pair.	
Copper.	zinc, liquid, copper.	zinc, liquid, copper.	zinc.

Hence, in using the very same plates, according to the former opinion, there are three pairs in full operation. But, according to the latter, there are only two, the zinc plate at one end, and the copper plate at the other, being of no use. Further, it will be observed, that in Volta's theory the zinc of the first pair, and the copper of the last are the true termini in the above arrange-

ment. But, on the chemical theory, these plates are excluded and considered of no use.

2687. When several troughs are to be connected together, so as to form a galvanic battery, great care must be taken to place them in such a position that the plates shall all be situated in the same manner with respect to each other as if they had been placed in a single trough; the zinc extremity of the one being connected with the copper extremity of another; Fig. 368 represents the best method of arranging eight small troughs together, so as to have the opposite poles brought within a convenient distance of each other.

2688. An extreme variety of arrangements has been adopted in constructing batteries, the effects being exceedingly different according to the manner in which they are filled up. Thus, two very large plates of zinc and copper may be powerful in producing heat and light, but will scarcely give any sensible shock, or exert a marked influence in promoting decomposition. But if they be cut into much smaller plates, they will now be powerful in the latter respects, and comparatively feeble in evolving heat and light.

2689. In the arrangement termed the COURONNE DES TASSES, a number of cups or cells are provided, and into these, when charged with liquid, the metallic plates are introduced, the zinc plate in one cell communicating with the copper plate in the next.

2690. In Wollaston's battery a plate of copper is exposed to each surface of zinc, and in some cases batteries have been made where a much larger surface of copper is opposed to the zinc. Dr HARE's CALORIMETER may be considered as a battery made of metallic coils, acted upon by liquid in the usual manner.

2691. An amalgam of zinc and mercury has been used by Mr Kemp instead of zinc plates. The amalgam being placed in a cup and opposed to a plate of copper. This arrangement is very convenient, especially in electro-magnetic experiments.

2692. A great variety of new arrangements has been proposed for the galvanic battery, founded more particularly on the researches of Faraday, Hare, Daniell, and Mullins. For a description of these the reader may consult the Philosophical Transactions, Philosophical Magazine, and the Annals of Electricity.

2693. Mr Young's battery is perhaps the most convenient and powerful that has hitherto been constructed for illustrating the decomposition of water. In it the plates are brought very near each other, and each surface of zinc is opposed to a surface of copper. It may be also used for producing light with charcoal points, for deflagrating metallic leaves, and other chemical experiments. The following description is taken from the Philosophical Magazine and Annals :—

2694. " The sheet copper and sheet zinc to be used in this battery are first cut into long ribbons, of the breadth which it is intended to give the plates. Suppose the ribbons two inches broad, both the copper and zinc ribbons are then divided into lengths of five inches, and a portion cut out as in Fig. 371. The slip is thus divided into two squares of two inches each, which are connected at A, and a piece is left projecting at B. The zinc and copper sheets are cut up exactly in the same way. Fig. 371, therefore, represents either a single zinc or a single copper plate. The plate is then bent at A, and presents the
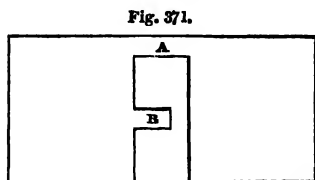
Fig. 371.
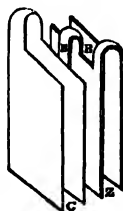
Fig. 372.   Fig. 373.

appearance represented in Fig. 372. In Fig. 373 we have two plates, one of copper C, and the other of zinc Z, which are exactly alike in construction, but are placed differently, as shewn in the figure. Thin projecting parts, BB, are soldered together, and this is the only metallic communication between them which is allowed to exist ; Fig. 373, therefore, is only one copper and one zinc plate, or it is one pair of plates. Each pair is made up in the same way. In arranging a number of pairs to form a battery, they are interlaced so that a copper square comes in between each couple of zinc squares, and a zinc square between each couple of copper squares. It is easy to see how this arrangement can be made when the plates are in the hand,

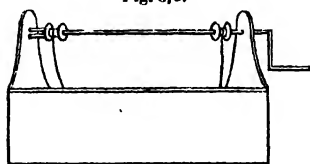though it is difficult to describe it. At the positive end of the battery there is a single copper plate which is soldered at the top to the last double copper plate, as seen in Fig. 374, which figure represents three pairs properly arranged, and also the manner in which they should be fitted up and kept steadily apart in a wooden frame. This frame consists of two cross-bars, ec, $éé$, in front, and the same behind, dovetailed into solid ends. The channels in the cross-bars for the reception of the edges of the plates, are formed by placing the four cross-bars together, and sawing a little way into one side of them all, every eighth of an inch or so in their length, so as to form a set of parallel grooves. We have by means of this frame a much greater security that no metallic contact will occur between contiguous plates, than when they are separated by wedges of cork, as in Dr Hare's construction, which may slip out.
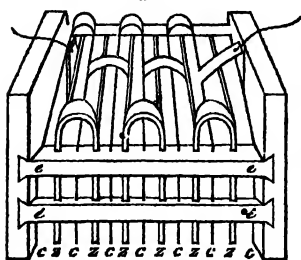
Fig. 374.

2695. " To the solid ends of the frame are attached two cards, which are fixed to two pulleys, on which they are wound up, on turning a winch, as represented in Fig. 375, by which means the frame and battery can be raised out of the fluid. If the axis (a stout wire) on which these pulleys are fixed can be moved a little backwards and forwards on its bearings, it is easy by means of a little projecting peg which fits into a hole in the side of the pulley, to fix and support the frame in a position above the trough, and out of the exciting fluid when that is desirable. But the form of the trough to contain the frame and plates may be varied according to the object in view, or the purposes to which the battery is to be applied.

Fig. 375.

2696. " A small battery of this construction containing twelve pairs of two inches breadth of plates (the size which we have taken above as an example) may be contained in a trough eight inches in length, and will evolve when its terminal wires are soldered to a Faraday Volta-electrometer, six or seven cubic in-

ches of the mixed gases in three or four minutes, with a charge of half an ounce of sulphuric acid and half an ounce of nitric acid in twenty-four ounces of water (all by fluid measure), and is therefore amply sufficient to demonstrate the decomposition of water on a considerable scale.

2697. " It is proper to use the thickest sheet zinc which can be had in the construction of the plates, although the thinnest sheet copper will suffice, from its being so well supported. When the zinc plates are worn out, the cross-bars may easily be pulled out of the solid ends, and the elements of the battery separated; new zinc plates being soldered to the old coppers, the whole may again be quickly arranged in the old frame."

. 2698. Since Professor Daniell's experiments in preparing a constant battery, that is, a battery which should not decline in its action, a great number of experiments have been performed, with the view of introducing batteries of this kind. The sustaining battery introduced by Mullins has been much employed, and has been worked in a variety of ways. The reader is reerred to the Annals of Electricity for details upon the subject. The annexed Figures (376, 377) shew one of the forms which

Fig. 376.   Fig. 377.
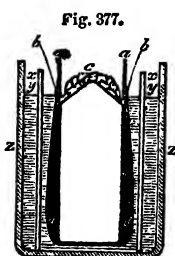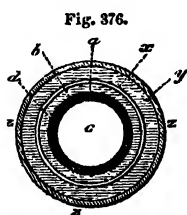
has come into general use. $a\,a\,a$, is a hollow copper vessel, surrounded by a membrane, and having a shelf near the top, on which crystals of sulphate of copper are placed. An aperture immediately below the inclined shelf, allows the solution of the sulphate to pass between a and the membrane; $b\,d$, is the solution of sulphate of copper. $x\,x\,x$, is a cylinder of zinc placed between the containing vessel $z\,z\,z\,z$ and the membrane b; y, the surface of the exterior fluid placed on either side of the zinc, which usually consists of sulphuric acid diluted with a large quantity of water, or of a solution of muriate of ammonia.

· Mechanical arrangements have also been proposed to obviate the effects produced by the deposition of impurities upon the metallic plates, which are thrown down in a loose form at first, and gradually aggregate afterwards, impeding to a great extent

Fig. 378.

zc   zc   zc
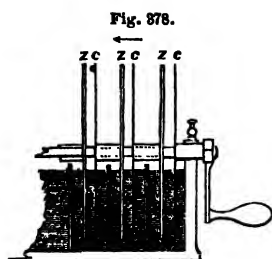
the galvanic action that would otherwise take place. In Mr Roberts's battery, the zinc and copper plates are circular, and made to rotate in separate cells, containing the exciting fluid. Fig. 378 gives a section of the cells, and plates of zinc and copper; and Fig. 379 shews its general appearance. The zinc and copper plates in the same cell are insulated from each

Fig. 379.
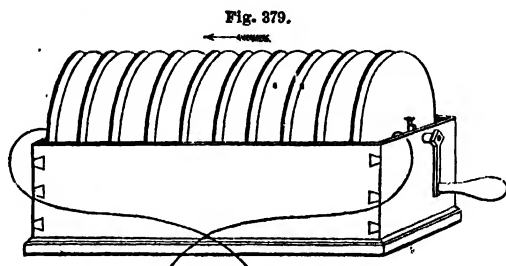
other by the support on which they rest, communicating, however, by the fluid in the usual manner. By placing bands of cloth or brushes between the plates of zinc and copper, they are always kept clean. As they are turned round, the permanent precipitation and adhesion of zinc upon the copper plate is prevented, and also the accumulation of oxide of zinc or hydrogen upon the zinc plate, so that an equality of action may be sustained for a long period when an acid solution of equal strength is maintained. Those sides of the plates that are united by metallic contact are covered with oil-paint, to protect them from the acid liquor.

EXPERIMENTS WITH GALVANISM.

2699. All experiments performed by the electrical machine may be imitated by the galvanic battery, and the converse equally holds true; but it is exceedingly difficult to substitute the battery or the trough for each other, so as to produce their various effects with the same facility, as the electricity in the electrical machine is high in intensity but small in quantity,

while that of the galvanic battery is the very reverse in these respects, the quantity being great, and the intensity small.   To produce the brilliant light evolved when electricity passes through charcoal points, let two copper wires be connected with the poles of the galvanic battery, and small pieces of charcoal, two or three inches in length, and about one-tenth of an inch in diameter, be tied to them by their copper wires.   They are prepared most conveniently by heating pieces of willow cut to a proper size, in a covered crucible filled with powdered charcoal.   The charcoal points may be approached so as nearly to touch each other.   The galvanic battery of 120 pairs of plates, four or six inches square, and charged with the stronger acid mixture mentioned, gives a

Fig. 380.
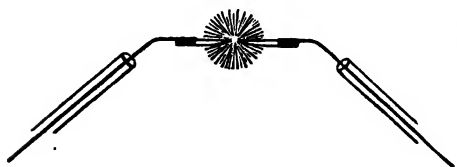
very brilliant light. Fig. 380 shews the general arrangement adopted, glass tubes being placed over the wires, that they may be held conveniently ; but, should the hands be very dry, they are scarcely necessary, galvanic electricity not passing readily through the dry cuticle.

Fig. 381.
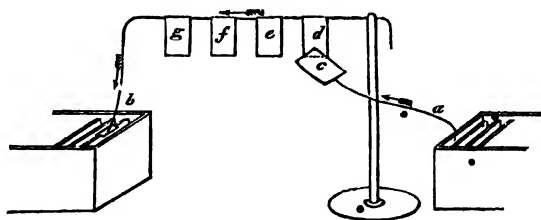
2700. To deflagrate metallic leaves, they must be exceedingly fine, and are generally supported, in the manner represented in Fig. 381, on a bent brass rod, fixed into one pole of the galvanic battery by one extremity, while the other rests upon a glass support.   Another wire from the other extremity of the battery terminates in a thick metallic plate c, which, when brought in contact with any of the metallic leaves b, e, f, or g, instantly completes the circuit, when the leaves are dissipated by the electric power.

2701. When exceedingly fine wires are to be acted upon, they

Fig. 382.

may be attached to a wire communicating with one pole, and brought in contact, either singly, or in a bunch, as represented in Fig. 382, with a metallic plate attached to the other pole of the battery.

2702. Gold, silver, and platinum are immediately dissipated, if the electric power be great in proportion to the amount of metal, but when it is small the electricity is transmitted without producing any effect upon the metal. Iron, tin, copper, and many other metals are oxidated. The wires should be frequently moved upon the metallic plate to shew the full effect.

2703. To detonate gunpowder, fulminating mercury, or any other compound of a similar nature, the best method of proceeding is to put it on a metallic plate connected by a wire with one of the poles of a battery, touching the upper portion with a similar wire connected with the other extremity. (Fig. 383.)
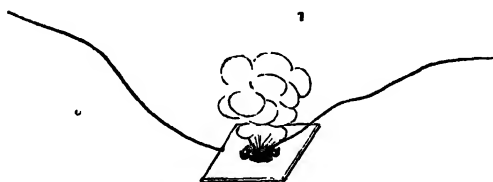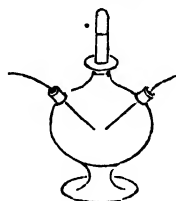
Fig. 383.

Fig. 384.

2704. Fill a tube with a diluted solution of sulphate of soda, and invert it under water, fixing it into an apparatus similar to what is represented in the above figure (384); one of the bottles of Woulfe's apparatus may be easily adjusted for this purpose, if the beginner should not have a globe with a tube ground to it. Then put two gold or platinum wires, connected with the positive and negative poles of the battery by copper-wires, into the tubulures at the sides through corks, and immediately a stream of gas will rise from both wires, and collect in the tube; the wires must not close the apertures in the corks completely, but allow part of the liquid to pass out, as it is

Fig. 385.
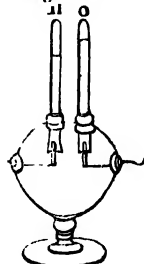
displaced by the gas. On examining the mixture, it is found to be composed of one measure of hydrogen, and half a measure of oxygen (a portion of water being decomposed), which may be easily detonated by withdrawing the tube and applying a light. Oxygen is evolved at the positive, and hydrogen at the negative wire, and they may be collected in separate vessels, by a modification of the apparatus, as represented in figure 385.

2705. Take two glasses filled with the same diluted solution of the sulphate of soda, connect them together by a piece of moistened cloth, and put a wire attached to the positive pole of the battery into one of the glasses, and one connected with the negative pole into the other. Water will be decomposed, as in the preceding experiment, and also the sulphate of soda;

Fig. 386,

in the former case, however, the sulphuric acid and soda detached from one another, meeting again in the same vessel, immediately combine and form sulphate of soda, so that they cannot be obtained separate from one another; but in the present case, all the acid passes into the glass connected with the positive pole, and the alkali into the other. If the solution be tinged with a little of the blue infusion of cabbage, the usual changes of colour take place, and indicate the change that is going on.
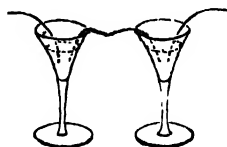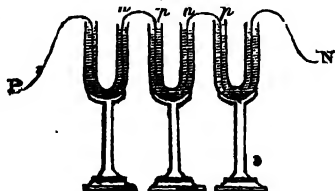
2706: By changing the position of the wires, the acid may be made to pass into the glass which previously contained the alkali in excess, while the latter takes the place of the acid.

2707. In both these experiments, the copper-wire connected with the positive pole of the battery, must have a piece of gold or silver wire attached to it, which alone is to be introduced into the liquid; a copper-wire is speedily oxidated as the water is decomposed, and the oxide combines at the same time with the acid of the sulphate, which is separated at the same pole.

2708. Instead of wine-glasses, tubes of the form shewn in figure 387 are often employed, the sulphate of soda solution being tinged blue by the common coloured cabbage. If the glasses or syphon be connected, however, not by MOIST-

Fig. 387.

ENED CLOTH, but by dry metallic platinum wires, the acid and

alkali do not then pass from one glass to another, and each extremity of every syphon tube becomes acid or alkaline in the manner represented.   By reversing the position of the wires, so that the electric current shall pass in the opposite directions, the acid and alkali may be made to exchange places.

2709. The beginner should perform some experiments, in the following manner, with various solutions, until he is familiar with the general nature of the decompositions affected by galvanic electricity. The extremities of two wires being connected with the poles of the battery, he may introduce them successively into the following solutions ; one or two drops only being used and spread upon a piece of glass, or upon a slip of test-paper, when it is desired to shew the acid or alkaline reaction.   For experiments with so small a quantity of materials, a very small trough, or a few plates, will be found amply sufficient, or a small voltaic pile may be employed as a substitute.

2710. I. SULPHATE OF SODA.   The sulphuric acid appears at the positive pole, and the soda at the negative.

2711. II. IODIDE OF POTASSIUM.   The iodine appears at the positive pole, and the potassium appears in the form of potassa at the negative pole ; water is also decomposed.

2712. III. SULPHATE OF MAGNESIA.   The sulphuric acid appears at the positive pole, and the magnesia at the negative.

2713. IV. METALLIC SOLUTIONS in general present the metal at the negative pole, when it is not powerful in decomposing water at ordinary temperatures, and as it is liberated from the solution. Acetate of lead, sulphate of copper, and nitrate of silver, present solutions of the common metals, which afford crystals with extreme facility, when acted upon by a weak galvanic current.

2714. In experimenting with galvanic apparatus, it is frequently necessary to change the direction of the currents.   This may be effected in most cases with facility by merely reversing the position of the positive and negative wires communicating with the apparatus employed.   But where this requires to be frequently done, Mr E. M. Clarke's ELECTREPETER will be found very convenient.   It is represented in Fig. 388, and consists essentially of a moveable frame supported on centres communicating with the positive and negative poles of any galvanic arrangement, by the cups P and N, each centre termi-

Fig. 388.
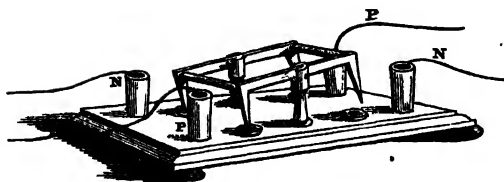
nating in two depending branches, either of which may be made to continue the electric current, when inserted in the metallic cup containing mercury, which is placed below it. An examination of the two following illustrative figures will explain its mode of action; in 389, it is seen arranged in the manner required when the electricity entering on one side, passes over to the opposite side.

2715. Figure 389 shews the direction the electricity takes through the electrepeter, passing onwards as represented by the
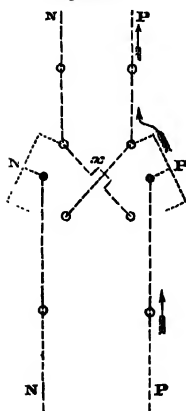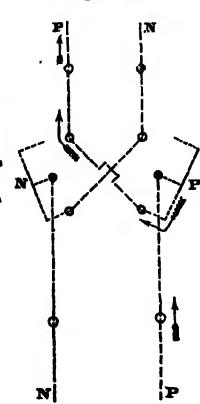
Fig. 389.   Fig. 390.

arrows and returning on the opposite side in the contrary direction from the subject of experiment. But in 390, the position of the moveable frame - work having been changed, the current is observed to reach the centre in the same manner as before, and then to cross over to the opposite sides, proceeding to and returning from the subject of experiment in a direction contrary to that which it formerly took. The positive and negative wires from the galvanic apparatus, are usually introduced into the posterior mercurial cups, and those leading to the subject of the experiment, into the anterior cups, all of these being connected with the wires on the lower side of the electrepeter, while the moveable frame-work rests above. In the two last figures, the two sides of the moveable frame are represented as if they were laid horizontally, that the connections of the different parts may be more distinctly traced; and though they are shewn in connection in Fig. 388, still it is essential that they shall not be united by any metallic conductor; x in Figs. 389 and 390, shews that one of the wires forms a bridge over the other, so as to cross it

without metallic contact.   It will now be seen that Fig. 388 and
390 refer to the same position of apparatus.

2716. The precise nature of the influence exerted by electri-
city on chemical action has not been minutely defined.   Sir
Humphrey Davy's view, that chemical action is dependent upon
the electrical relations of the elements and their compounds,
has been very generally adopted.   All elements and compounds
are considered to have a peculiar relation to electricity, in con-
sequence of which they appear at the positive or negative poles
of the galvanic battery ; but the pole at which they are evolved
varies under different circumstances, so that an element which
appears at the positive pole when detached from one combina-
tion, may be evolved at the negative when liberated from an-
other.   They are all supposed to have, or to acquire, a different
electric condition from that of the pole to which they are at-
tracted, and hence ELECTRO-NEGATIVES is the term applied to
those which appear at the positive pole, while ELECTRO-POSITIVES
are those that are attracted to the negative pole.   The follow-
ing table by Berzelius illustrates his arrangement.

ELECTRO-NEGATIVES.	ELECTRO-POSITIVES.
Oxygen.	Potassium.
Sulphur.	Sodium.
Nitrogen.	Lithium.
Chlorine.	Barium.
Iodine.	Strontium.
Fluorine.	Calcium.
Phosphorus.	Magnesium.
Selenium.	Glucinum.
Arsenic.	Yttrium.
Chromium.	Aluminum.
Molybdenum.	Zirconium.
Tungsten.	Manganese
Boron.	Zinc.
Carbon.	Cadmium.
Antimony.	Iron.
Tellurium.	Nickel.
Columbium.	Cobalt.
Titanium.	Cerium.
Silicium.	Lead.
Osmium.	Tin.
Hydrogen.	Bismuth.
	Uranium.
	Copper.
	Silver.
	Mercury.
	Palladium.
	Platinum.
	Rhodium.
	Iridium.
	Gold.

2717. Oxygen is always separated at the positive pole, and potassium at the negative; other substances appear at different poles, according to the compounds from which they are separated. Acids and highly oxygenated bodies appear at the positive pole; but hydrogen, inflammables, and metals, are commonly separated at the negative pole. When elements belonging to the same class are separated from each other, they appear at different poles.

2718. Elements and compounds under the influence of electrical action often lose those powers of attraction which they may formerly have had, and acquire others. An acid, for example, may be transmitted through ammonia, potassa, soda, and other substances with which it would combine under ordinary circumstances, no combination whatever ensuing when moving by the influence of electricity.

2719. Great additions have been made of late years to this department of electrical science, especially by Dr Faraday and Mons. Becquerel, whose investigations perhaps, are next in importance to those of Sir Humphrey Davy. Mr Faraday's papers were printed originally in the Philosophical Transactions, and M. Becquerel's treatise on Electricity contains a full compendium of his views; and particularly of the modes adopted for producing artificial minerals. The following brief summary contains a condensed sketch of the more important circumstances pointed out by Faraday.

Dr Faraday's Researches.[*]

2720. Dr Faraday has confirmed by numerous experiments the views that have been generally adopted as to the identity of the electricity of the electrical machine and of the galvanic battery; a piece of paper, moistened with a solution of iodide of potassium and starch, was found of much use as a test of electricity in his researches, the iodine being set at liberty and rendering the starch blue. The great difference in the chemical agency of the electricity of the electrical machine and the galvanic battery, is explained by a comparison of the quantity of electricity produced by each. *An electric battery of 15 jars, each containing* 234 *square inches of glass coated on each side, and*

[*] This account is taken principally from my text-book.

charged by 30 *turns of a powerful plate electrical machine,* 50 *inches in diameter, yields no more electricity than a platina and a zinc wire, each* 1–18th *of an inch in diameter, placed* 5–8ths *of an inch deep, in a diluted acid composed of* 1 *drop of sulphuric acid and* 4 *ounces of water, during* 3 *seconds.* Again, the quantity of electricity associated with the elements of bodies in their various chemical combinations is so great, *that, while electricity sufficient to decompose a grain of water can be easily procured during the chemical action of a few grains of zinc on a diluted acid, Dr Faraday has inferred that no less than* 800,000 *charges of the electric battery just mentioned would be necessary to produce the same effect.*

2721. The conducting power of bodies has long been known to influence much the manner in which they are affected by electricity. Dr Faraday has added the following remarks from an extensive series of observations. Water was stated by Davy to be essential to electro-chemical decomposition; but this opinion can no longer be maintained.

2722. "All bodies conduct electricity in the same manner from metals to lac and gases, but in very different degrees.

2723. "Conducting power is, in some bodies, powerfully increased by heat, and in others, diminished, yet without our perceiving any accompanying essential electrical difference, either in the bodies or in the changes occasioned by the electricity conducted.

2724. "A numerous class of bodies insulating electricity of low intensity when solid, conduct it very freely when fluid, and are then decomposed by it.

2725. "But there are many fluid bodies which do not sensibly conduct electricity of this low intensity; there are some which conduct it and are not decomposed; nor is fluidity essential to decomposition.

2726. "There is but one body yet discovered which, insulating a voltaic current when solid, and conducting when fluid, is not decomposed in the latter cases.

2727. "In numerous cases, as a solid becomes fluid, it loses almost entirely the power of conduction for heat, but gains in a high degree that for electricity," and *vice versa.*

2728. The extremities or poles of an electric circuit are usually spoken of as having peculiar attractive and repulsive powers, to which the chemical agency of electricity has been

referred ; and Davy, with other chemists, considered that the decomposing agency was feebler in other parts of the circuit than at the poles.   But Faraday's views are different; the force of the electric current is equal, he considers, throughout all the circuit, and that it is more correct to speak of the particles acted on by the electricity in relation to the current passing through them, than to the poles, which are merely the doors through which it passes.

2729. The transferring power of electricity, by which the particles are made to appear at different poles, is much influenced by the attractive power of the substances associated with them.   Thus more sulphuric acid is carried to the positive pole of a battery, if it be combined previously with soda, which attracts it strongly, than when merely combined with water, which has a weaker affinity for it.

2730. Elements, and other bodies not decomposable, are not affected by an electric current, unless in chemical relation to other matter.

2731. No determination to a pole has been observed in cases of mere mixtures.

2732. Decomposition is attributed, therefore, not to the agency at the different poles, but to the electricity as it affects each particle while it passes in a current.

2733. Again, among the more remarkable circumstances attending electro-chemical decomposition, the appearance of the elements at a distance from each other is to be particularly noticed.   This does not arise from their being attracted to the poles, but from the compound being decomposed at each pole, the electricity producing a like effect at every part of the compound through which it passes, so that a series of combinations and decompositions take place throughout the substance acted upon between the poles.   Thus, if

OH   OH   OH   OH   OH   OH   OH
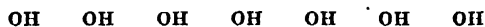
represent seven particles of the compound OH, consisting of O and H, placed between the poles of a galvanic battery, then the following arrangement is produced :—

O   HO   HO   HO   HO   HO   HO   H

This is the only explanation at all satisfactory which has been

offered of the appearance of the elements of a compound at the different poles, often widely separated from each other.

2734. In numerous cases, the substances that appear at the different poles, are the SECONDARY, not the PRIMARY PRODUCTS of electro-chemical decomposition, being formed or disengaged by the primary products decomposing or combining with some of the substances with which they come in contact as they are evolved.

2735. Metals which have been connected with the positive pole of the galvanic battery have been observed, even when entirely removed from it, to have the power of promoting combination; this was tried more particularly in reference to the action of oxygen with hydrogen gas. On a careful examination of the causes of this supposed electric action, it was found to depend on the surface being thoroughly cleaned in the liquid in which they were immersed, and that similar effects were produced when platinum, the metal preferred in these experiments, was carefully cleaned by sulphuric acid and water.

2736. Bodies directly decomposable by electricity have generally been found to consist of 1 equivalent of each element; and in simple binary compounds this has always been observed to be the case.

2737. "The chemical power of a current of electricity is in direct proportion to the absolute quantity of electricity which passes."

2738. The electricity which decomposes, and that which is evolved by the decomposition of a certain quantity of matter, are alike.

2739. The quantity of electricity required for the decomposition of an equivalent weight of a simple binary compound (consisting of 1 equivalent of each element), is the same with that necessary to effect the decomposition of an equivalent quantity of any similar binary compound.

2740. The term ELECTRO-CHEMICAL EQUIVALENTS refers to the quantities of substances separated from any compound by a given amount of electricity; and referred to a standard of comparison, they are found to approximate as nearly as could be expected to the ordinary equivalent numbers.

2741. The definite nature of electro-chemical action, and the correspondence between the chemical equivalents of bodies as-

certained in the usual manner, and from the quantity separated by a given amount of electricity, are equally novel and important in the history of chemical science.

2742. In pursuing his researches, Dr Faraday found it necessary to employ an instrument which he contrived with the view of measuring the quantity of electricity produced, and employed in different experiments. Having shewn that the chemical decomposing action of a current of electricity is constant for a constant quantity, however variable in its course, in its intensity, and in the nature of the poles and conductors employed, water was chosen to indicate the strength of the current passing through it by the quantity decomposed, being acidulated with sulphuric acid to make it a better conductor. The apparatus employed consists of a vessel containing the fluid, in which two wires or plates of platinum are introduced, placed at a little distance from each other. The wires being connected with the galvanic battery, so as to form part of the circuit, the quantity of water decomposed at the same time that other effects are produced by passing the electricity through different substances in another part of the circuit, affords an excellent standard of comparison. The instrument is termed the VOLTA ELECTROMETER, or VOLTAMETER.

2743. Mr Roberts has introduced a form of Voltameter which is represented in the annexed Fig. 391. PN shew the wires connected with the battery disengaging gas in the usual manner, in water acidulated with sulphuric acid; the amount of gas evolved is measured by the space it occupies in the graduated tube. The accumulated gas is allowed to escape by opening the stopcock, the acid liquid then descends in the opposite stem, fills the space from which the gas has been expelled, and the instrument is now ready for a new observation.

Fig. 391.
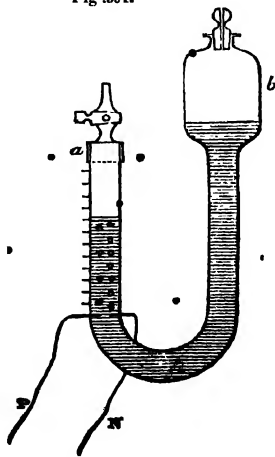
2744. Dr Faraday has introduced the following new terms, to save circumlocution, and express more specifically than he could with those now in use many of the circumstances attending electro chemical decomposition.

2745. ELECTRODES, from ηλεκτρον and οδος; a way, used instead of poles, as they are regarded merely as the doors by which electricity passes; they are the boundaries of the decomposing matter in the direction of the electric current.

2746. ANODE, ανα, upwards, and οδος, a way; that part of the surface of a decomposing body which the electric current enters; the part immediately touching the positive pole.

2747. CATHODE, κατα, downwards, and οδος; that part of the decomposing body which the current leaves; the part next to the negative pole.

2748. ELECTROLYTES, ηλεκτρον and λυω, I separate; a body which can be decomposed directly by electricity. ELECTROLYZED means electro-chemically decomposed.

2749. ANION, ανιον, that which goes up; a body which passes to the positive pole, to the anode of the decomposing body, as it is separated by electricity.

2750. CATION, κατιον, that which goes down; a body that passes to the negative pole, to the cathode of the decomposing body. IONS signify anions or cations.

Effect of Galvanic Electricity on Animals.

2751. Galvanic electricity differs principally from the electricity of the electrical machine, in having a very low degree of tension, while its quantity is great, and sustained continually so long as the strength of the acid mixture commonly employed is kept up. For medical purposes, where it is frequently to be used, many prefer it to the electricity of the electrical machine, that part of the body to be subjected to its action being made, in the usual manner, part of the circuit, and placed accordingly between the positive and negative poles of the galvanic battery.

2752. Mr Kemp has recommended the following method to be adopted, where it is considered advisable to avoid the shock communicated, on making or breaking contact. The connection being made between one pole of the battery and one extremity of the part through which the electricity is to be passed, a metallic plate or ball terminating in two wires, is to be employed in completing it. The plate or ball being placed on the other extremity of the part alluded to, one of the terminating

wires is made to touch the pair of plates next to the pole of the battery first connected. While this connection is maintained, the other wire is moved beyond it, and then, the first lifted past it again, taking care always to maintain the connection with one wire, while the other is moved forward to include an additional number of plates. Care must be taken that the wires shall be moved back in the same manner they were advanced before the connection is entirely broken.

2753. Galvanic electrity having an extremely feeble tension, does not pass through the dry cuticle, and hence it is necessary to moisten it with a solution of salt or with vinegar, in passing electricity through the body.

2754. As a great variety of susceptibility is observed in different individuals in reference to the electric fluid, great care should be taken in giving a galvanic shock to an invalid with a strong battery; some individuals are but slightly affected by shocks which affect others with violent convulsive movements. Perhaps the coil machine, described in the succeeding chapter, is better adapted for medical purposes, than any other form of electrical apparatus which has hitherto been invented.

CHAP. IV.—MAGNETIC ELECTRICAL MACHINE, &c.

2755. Since Oersted laid the foundation of the science of electro-magnetism, by his important discovery of the influence of a galvanic current upon the magnetic fluid, few branches of science have advanced with such extreme rapidity, more especially by the additional researches of Ampere, Biot, and Arago, on the continent, and of Davy, Faraday, Ritchie, and Barlow, in this country. The production of an electric spark, by the action of a magnet, in the experiments of Nobili and Antinori, Forbes, and Faraday, have added much to the interest of this subject, and also the invention of an instrument by Pixii, for producing the electric spark continuously, and of another by Saxton. Those who are desirous of studying this subject, are referred to Roget's Treatise, in the Library of Useful Knowledge, to the works of Ampere, Cumming, and Murphy, to the

Philosophical Magazine, and to the Annals of Electricity, &c., conducted by Mr Sturgeon.   Faraday's researches will be found in the Philosophical Transactions.

2756. Any galvanic arrangements may be employed to illustrate the action of an electric current upon the magnetic fluid ; but when a single pair of plates is used, few arrangements will be found more convenient than that represented in the three following figures, 392, 393, 394.   These give a sketch, a section, and


Fig. 392.   Fig. 393.   Fig. 394.
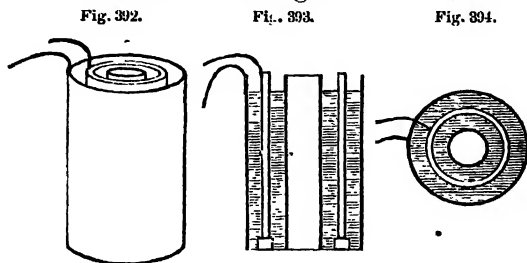
a ground plan, of a circular pair of plates, in which a thick cylinder of zinc is introduced into a circular cell of copper, both surfaces of the zinc being opposed to a surface of copper ; the zinc rests on baked wood, or glass, so as not to be in metallic contact with the copper.   This arrangement is usually excited by dilute sulphuric or nitric acid, the strength being increased in proportion to the effect required.

2757. Connect the extremities of a galvanic battery, or of a single pair of plates with a metallic wire, and approach to it a magnetic needle, it is instantly deflected, if placed above or below the wire, but if arranged in the same plane the needle tends to move vertically.   The extent of deviation is influenced by the magnetism of the earth, and if this be counteracted by the action of another magnetic needle ; it will then be seen that the magnetic needle tends to assume a direction at right angles to an electric current.

2758. A magnetic needle, *a b*, figure 395, placed so as to be surrounded in the manner represented by a metallic wire, the extremities of which are arranged so as to be easily connected with the wires proceeding from the poles of any


Fig. 395.
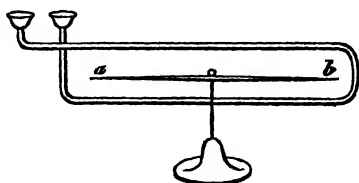
galvanic apparatus, is usually termed a GALVANOSCOPE, or GAL-
VANOMETER.

2759. If, instead of a single coil, a large wire shall be em-
ployed, which shall be thrown in numerous convolutions round
the needle *a b*, in the preceding figure, it then forms SCHWEIG-
GER'S MULTIPLIER, each convolution increasing the influence of
the current made to pass through it. In this case, the wire
must be covered by a silk-thread to prevent a spark passing from
one convolution to another. In the *thermo-multiplier* of Melloni,
described in the succeeding chapter, N shews this form of the
instrument, the suspended needle being rendered ASTATIC by
another needle placed opposite the first and parallel to it, but in
a reverse position, the north pole of one being placed against the
south pole of the other. In this astatic needle, the indications
are more delicate, the more perfectly the influence of the one is
neutralized by that of the other, previous to the action of the
galvanic current.

2760. So intimate is the connection between *Light, Heat,
Electricity, Magnetism,* and *Chemical action,* that all these may
be observed in operation at the same moment in numerous expe-
riments. If a copper wire be coiled round a piece of soft iron
previously thrown into the form of a horse shoe, and an electric
current be passed through it, in the manner represented in
figure 396, the CHEMICAL AC-
TION takes place between the
zinc and exciting fluid employ-
ed ; the development of HEAT
is indicated by the rise of tem-
perature ; LIGHT is observed
when the extremities of any of
the wires are taken out of the
small connecting cups filled with
mercury ; ELECTRICITY passes

Fig. 393.
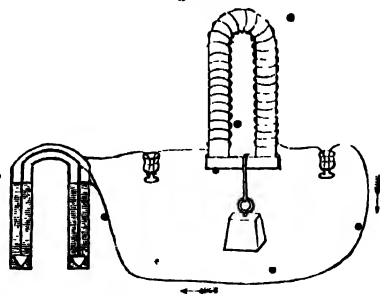
through the circuit, in the manner indicated by the arrows, and
renders the iron MAGNETIC, which can now be made to support
a very considerable weight. But if the electric current be in-
terrupted for a moment, by lifting any of the wires out of the
mercurial connecting cup, the iron loses its magnetic power,
and the weight falls to the ground.

2761. In examining the influence of electricity upon magnets,

a power or force is considered to act tangentially upon their poles, and perpendicularly to the direction of the current. A magnetic pole loosely suspended tends to move round a pole, as Faraday pointed out. For this purpose, a conducting wire is introduced into a vessel nearly filled with mercury, one pole of a magnet, Fig. 397, projecting beyond the mercury, while the other is attached by a thread to the conducting wire which carries off the electric current. The magnetic pole revolves round the conductor when the extremities of the two wires are connected with the galvanic battery. On the other hand, if the magnetic pole be fixed in the vessel employed to contain the mercury, and one extremity of the conducting wire be left free liberty of motion, as in the following figures, 398, 399, then the conducting wire rotates around the magnet.
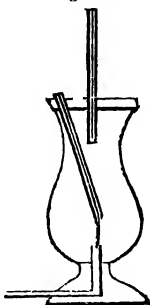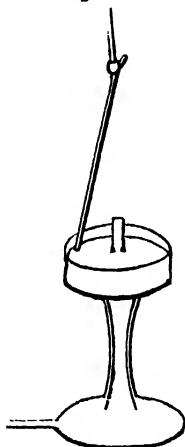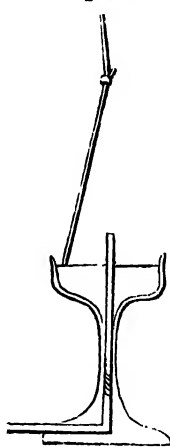
Fig. 397.

2762. In the MAGNETIC ELECTRICAL MACHINE of Pixii and Saxton, the electricity developed is induced in a copper wire, coiled round the keeper of a magnet—the keeper is the bar that unites the opposite poles of the magnet. It is placed at right angles to the poles of the magnet, and a magnetic current flows through it, or is induced in it, as it is brought in contact with the poles, being destroyed again

Fig. 398.   Fig. 399.

as it is withdrawn or turned in another direction. But when the keeper is magnetic, electric currents are induced in the surrounding coil, and the extremities of the coil are separated from each other as the keeper leaves the magnet, that successive electric sparks may be developed so rapidly as to maintain a continued light.

2763. With the electricity developed in this manner, all the ordinary effects of this power may be produced. The following description of the magnetic electrical machine, made by Mr

E. M. Clarke, Lowther Arcade, London, and with the improvements he has introduced, is taken from the Annals of Electricity, and illustrates the manner in which it is used. The letters apply to figures 400, 401, 402, and 403.

Figs. 400, 401, 402, and 403.
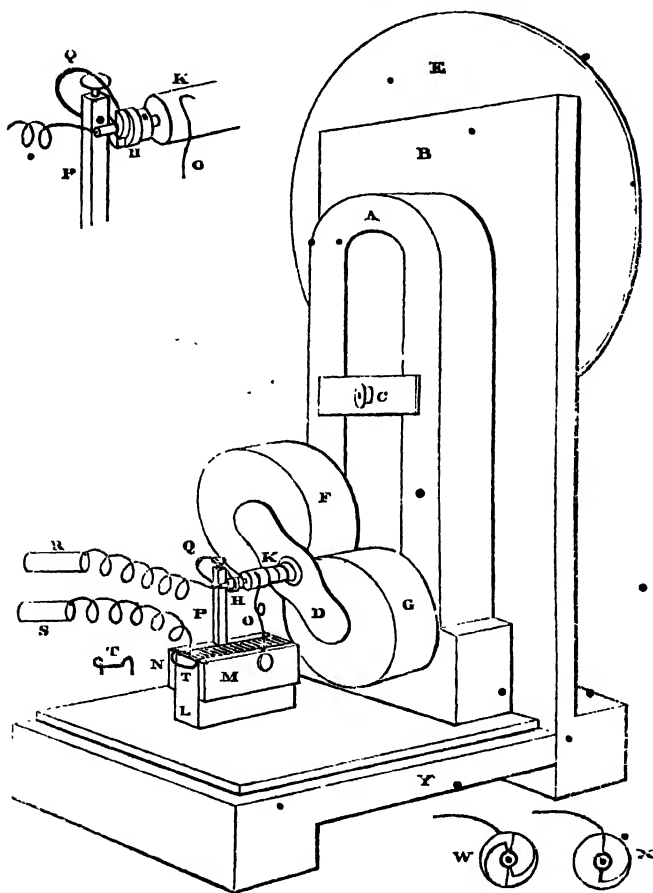
2764. A is a battery of bent bar magnets, placed *vertically*, and resting against four adjusting screws, which pass through the mahogany back-board B ; C is a bar of stout brass, having an opening in the middle, through which passes a bolt with a screw, the purpose of which is to draw the magnetic battery to the board B. By these means, the battery can readily be dis-

engaged from the machine without taking asunder the entire apparatus ; and the battery is thus also freed from that vibration which must necessarily be occasioned by the attachment of the rotating apparatus to the battery itself.   D is the intensity armature, which screws into a brass mandril seated between the poles of the battery A, motion being communicated to it by the multiplying wheel E.   This armature has two coils of fine insulated copper wire, 1500 yards long, coiled on its cylinders, the commencement of each coil being soldered to the armature D, from which projects a brass stem (also soldered into D) which carries the break-pieces H and H.   The break-piece is made fast, in whatsoever position it may be required, by a small binding screw.   K and K is a hollow brass cylinder, to which the terminations of the coils F G are soldered, being insulated by a piece of hard wood attached to the brass stem.   O and O are hollow wire springs, pressing against the hollow cylinder K at one end, and held in metallic contact by a screw in the brass strap M, which is fixed to the side of the wooden block L.   P and P is a square brass pillar, filling into a square opening in the other brass strap N, and secured at any convenient height required.   Q and Q is a metallic spring that rubs gently on the brass piece H, and held in perfect metallic contact by the screw in P.   T and T is a piece of copper wire for connecting the two brass straps M N ; then D, H, Q, P, N, are in connection with the commencement of each coil, and K, O, M, with the terminations.

2765. The machine is brought into action by turning the multiplying wheel, when the coils F G evolve rapidly, the extremities of the wires which terminate in the eccentric break H and the wire pressing upon it, separating from each other at the same time that the armature leaves the poles of the magnet.

2766. Two different armatures are employed with this machine. The QUANTITY ARMATURE, for producing the spark, consisting of a thick wire ; while the INTENSITY ARMATURE, for producing the shock, and effecting chemical decomposition, consists of a much longer, but smaller wire.

2767. W and X represent the different modes in which the breaks are arranged, according as a double or single break is required in each revolution.   These BREAKS are essential to facilitate the separation of the extremities of the wires ; and,

when a single break is used, the electric current always moves in one direction ; but, when the double break is employed, the current is excited, and reversed at each revolution of the coils F and G.

2768. " To ADJUST THE INTENSITY ARMATURE. See that the faces of the iron cylinders that carry the coils F G, Fig. 400, are parallel to, and all but in contact with, the magnetic battery A. If not, unscrew the nut of the multiplying wheel E, and take it off its axis. You then have at your command the four screws against which the battery rests. By means of them, and the nut of the strap C, you can adjust the battery to the greatest nicety. The next step is to adjust the break, so that the spring Q will separate from it at the same time that the iron cylinders of the armature have left the poles of the magnetic battery ; and lastly, see that the iron wire spring O, presses gently against the hollow brass cylinder K."

2769. To GIVE THE SHOCK. Grasp the two brass conductors R S in the hands ;* put one of their connecting wires into the holes of either of the brass slips M or N, the other wire into the hole at the end of the brass stem that carries the break H ; connect M and N by T ; turn the multiplying wheel in the direction of the arrow ; and a violent shock will be received by the person holding R S. The shock which is obtained from the intensity armature, having 1500 yards of fine insulated wire, is such, that a person, even of the strongest nerves, will not readily volunteer to receive a second shock if the machine be worked quickly.

2770. Place R S in two separate basins of salt and water, immerse a hand in each basin, and the shock will also be felt very powerfully. This method is to be preferred, as it leaves the person who is electrified the power of quitting when he pleases. Not so with the conductors, for then the muscles of the arms often contract violently, so as to close the hands completely on the conductors, taking away the power of letting them go unless the assistant instantly ceases to turn the wheel E. If the two connecting wires of R S are put in M N, the shock is not so powerful.

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* If the hands are moistened with vinegar, or salt and water, the effect is considerably increased.

2771. The Decomposition of Water. For this purpose, the apparatus represented in the annexed Figure (404) is attached to the machine. A is a glass vessel, having a brass cup with hard wood bottom, through which two pieces of copper wire pass, having pieces of platina wire soldered to them. Place this in M N. Fill the tube B with water. Place it over the platina wires, where it will be held by the cork C. Q must rub on the cylindrical part of the break H. Here the gases are obtained mixed. By using one tube over each wire, the gases may be obtained separately. The operation advances quicker with a solution of sulphate of soda instead of water.
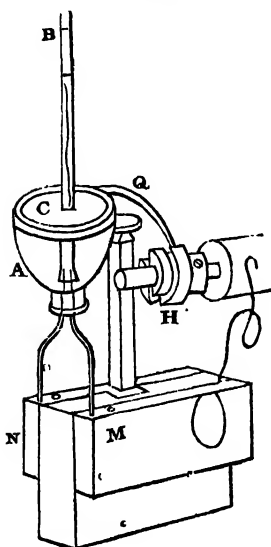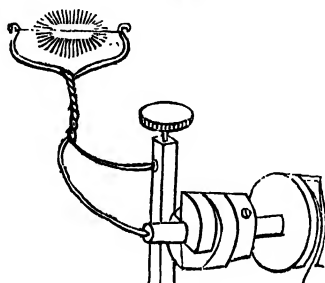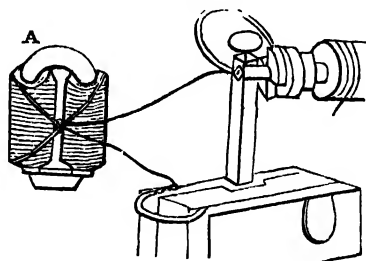
Fig. 404.   Fig. 405.

Fig. 406.

2772. To make platina wire red hot. Figure 405 shews the arrangement for this purpose. While the platina wire is red hot, ether may be inflamed, gunpowder exploded, and other experiments of a similar nature performed.

2773. To render soft iron magnetic. In Figure 406, A is a piece of soft iron, bent as in the figure, with a soft iron keeper, which adheres to the iron on the connection being made as represented, so long as the machine is in action.

Fig. 407.
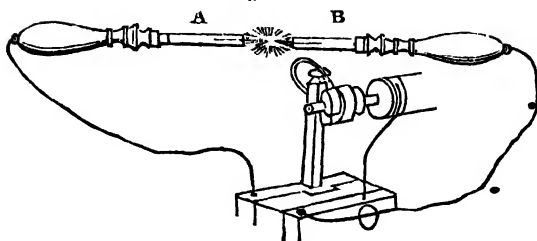
2774. To IGNITE CHARCOAL. Figure 407 represents the arrangement of the apparatus for this purpose. The same directors that are used to hold the sponges may be used to retain the charcoal points A B in their proper position (page 738).

2775. The COIL MACHINE consists of a primary and secondary coil of copper wire, the first being excited by a galvanic current, and inducing electricity in the second coil which surrounds it, the extremities of the latter being employed for communicating the electric shock. The annexed Figure (408) illustrates its construction, the thick wire through which the electricity is transmitted from the galvanic apparatus being wound upon a cylinder of wood, while the secondary coil is represented by a thinner dotted line.

Fig. 108.

2776. In giving shocks with the coil machine, the communication between the exciting galvanic apparatus and the coil should be frequently broken. One of the simplest methods consists in interposing a file between it and the galvanic apparatus (Fig. 409), upon which the connecting wire is made to move backwards and forwards, contact being continually renewed and broken by its unequal surface.

Fig. 409.

2777. In the complete coil machine represented in the annexed Figure (410), instead of a coil, a wheel with many teeth is employed as a break, the contact being made and broken as the wire pressing against the wheel or break passes from one to another; or the break proposed by Mr Nesbitt, and represented in the Figure, may be adopted, the interstices between the teeth being filled with wood, so as to enable the machine to work more
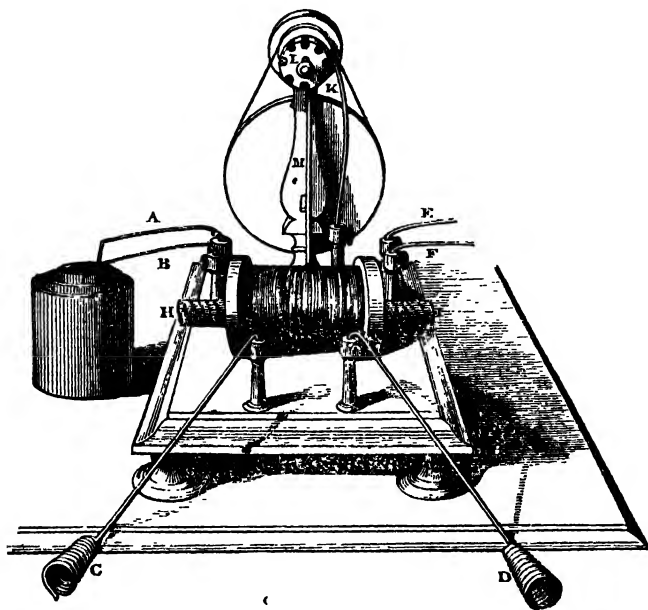
easily, while the contact is broken every time the wire rests on the small pieces of wood, being renewed again as it touches the metal.   A B are the connecting wires leading from the galvanic apparatus to the primary coil ; K, a continuation of A resting upon the break L, from the centre of which, on the other side, descends the wire M, terminating in the primary coil ; C D, the extremities of the secondary coil, with proper handles for communicating the shock to any individual who may lay hold of them ; E F, wires connected with the primary coil for communicating the shock it produces, or producing any other galvanic effect.

2778. This machine, though excited by a comparatively weak galvanic apparatus, gives shocks so powerful, that few or none can withstand them when the multiplying wheel is turned rapidly, which must always be moved before the apparatus is brought into action.   If a bar of iron, or a bundle of small pieces of iron wire, be placed in the centre of the coil, as H I, the power of the apparatus is greatly increased.   In Fig. 409, the illustrative

transverse section of the coil apparatus, x shews the aperture in the wooden cylinder into which the iron is introduced.

2779. No apparatus is more convenient for the communication of electricity for medical purposes than the coil machine, as its effects can be regulated with so much precision, according to the strength of the galvanic apparatus with which it is excited, and the rapidity with which the multiplying wheel is turned.

2780. In all experiments with electricity in motion, it ought to be particularly recollected, as Faraday pointed out, that an electric current from a galvanic circuit passing through one helix *induces an electric current in another adjacent helix, only at the moment that the circuit between the first helix and the galvanic apparatus is made or broken.*

2781. Again, as wires conducting galvanic electricity can produce motion in magnets properly supported for this purpose, so also, if the exciting galvanic apparatus be removed, and the ends of the wires be brought into metallic contact, then, on producing similar motions by a mechanical action, the same electric condition is induced in the connecting wire that is excited by the battery.

## CHAP. V.—THERMO-ELECTRICITY—MELLONI'S THERMO-MULTIPLIER—PELTIER'S HYGROMETER.

2782. The discovery of the development of electricity by the action of heat, or of THERMO-ELECTRICITY, as it is usually termed, is due to Dr Seebeck. Becquerel has made many interesting investigations in this branch of science, and Sturgeon, Cumming, Melloni, Peltier, and other distinguished experimentalists, have also made important investigations in the same field.

2783. Seebeck employed a very simple apparatus at first, in which a metallic circuit, composed of two metals soldered at their extremities, produced the electric current, one of the solderings being heated, while the other was maintained at a different temperature. Becquerel has shewn that electricity may be developed even in a metallic circuit composed of a single metal,

more especially by collecting the metal in unequal quantities at different parts.

2784. In the THERMO-ELECTRIC PILE, a series of bars of bismuth and antimony are usually employed, the extremities being soldered to each other, and arranged, so that each alternate connection may be heated while the other is cooled. An extreme variety of arrangements may be adopted in the disposition of the pile. It may be thrown into the form of a ring, or arranged in the zig-zag manner shewn in Melloni's thermo-multiplier, or in Peltier's hygrometer. The annexed Figure (411) represents a

Fig. 411.
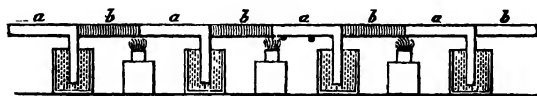
form of the apparatus which is frequently used in illustrative experiments. It consists of bars of bismuth *(a)* and of antimony *(b)*, those of bismuth terminating in an appendage which can be placed in ice, and maintained at a low temperature, so as to keep the solderings next them cool, while the others are heated by lamps. On connecting the extremities, the galvanometer being interposed, an electric current is indicated by the deflection of the needle.

2785. The THERMO-MULTIPLIER is an extremely delicate thermoscope, indicating deviations of temperature so small, that it is acted upon by the heat radiating from any individual, although it may be placed at a distance of twenty or thirty feet. It consists essentially of a series of thermo-electric couples, and of a galvanometer with an astatic needle. The first constitutes the thermoscope, but the latter is essential to indicate its action. The heat excites electric currents in the couples; and its extremities being attached to the metallic wires of a galvanometer, the magnetic needle is deflected, according to the intensity of the calorific influence.

2786. Two kinds of thermo-multipliers are employed, one in which the couples are blackened with smoke, for experiments with radiant heat. In the other they are left brilliantly metallic, and used for experiments with heat communicated by conduction.'

2787. The annexed Figure (412) shews the mode that may

be adopted in arranging the antimony and bismuth employed, the extremities of which are soldered together, so as to form a continuous metallic chain, disposed in parallel rows communicating by their nearest extremities. It is unnecessary almost to remark, that the bars of antimony and iron must not touch each other except at their soldered extremities, and that they must also be equally prevented from touching, by metallic contact, the circle which supports them.
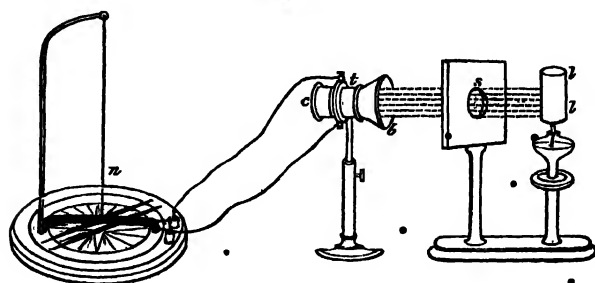
Fig. 413.   Fig. 414.   Fig. 412.
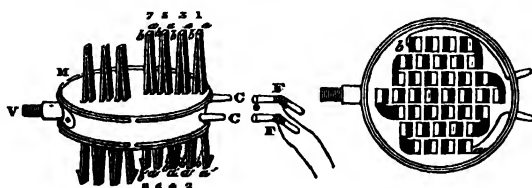
2788. It will also be observed, that the soldered extremities represented by the uneven numbers, 1, 3, 5, &c. (Fig. 413), appear on one side or face of the pile, while the even numbers, 2, 4, 6, &c., are seen on the other, and constitute the second face of the pile. F F (Fig. 414) are the connectors by which the extremities C C are attached to the galvanometer.

Fig. 415.

2789. In the next Figure (415), the circle *t* contains the thermo-electric couples, which are supposed to be acted upon by the radiant heat falling upon one of the faces of the solderings opposed to the rays. · A section of a conical metallic tube *b*, is attached to it, which performs the office of a reflector, while the other side is connected with a cylindrical tube *c*. The heat acting upon the extremity is disengaged from the lamp burning within *l*, and passes through the aperture in the screen *s*, where

any material to be subjected to experiment is placed, the amount
of heat transmitted being indicated by the deflection produced
in the compound astatic needle of the galvanometer *n*.

2790. The screw V, in Figs. 412 and 413, serves to fix the
couples in a proper situation upon the support, so that they may
afterwards be turned in any direction required.   The letters *a b*
shew the successive bars of antimony and bismuth.   C C should
be soldered to F F, to ensure a perfect metallic connection.   It
is scarcely necessary to remark, that, in the complete view of the
thermo-multiplier given in Fig. 415, the circle *t*, containing the
couples, is placed in a perpendicular position, one set of solder-
ings being opposed to the radiant heat, while the other is turned
in the contrary direction.   But, in Figs. 412 and 413 a different
position is given, that the connection and arrangement of the
bars may be more distinctly understood.

2791. The tubular reflector *b* is often dispensed with in some
experiments ; but in others, where the rays are not projected
directly upon the exposed extremity of the pile, it is of great use,
by collecting and reflecting inwards those rays that might other-
wise be lost.

2792. PELTIER'S ELECTRIC HYGROMETER* is founded on the
same principle as Leslie's, the cold produced by evaporation be-
ing taken as the indication of the dryness of the air ; the greater
the cold the greater the evaporation, and consequently the
drier the air.   The reduction of temperature is measured by a
thermo-electric apparatus, represented in the annexed figure.
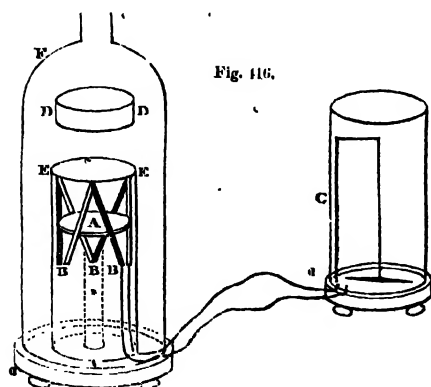

Fig. 416.

416. B B B, three couples
of bars of antimony and
bismuth, forming the ther-
mo-electric pile ; A is a
disc of wood by which it
is sustained, being fixed
by a screw attached to
the lower part of the ap-
paratus ; E a cylinder of
card ; F, a receiver co-
vering the whole appa-
ratus ; C, the galvanome-
ter, the needle only being

From Becquerel's Traité d'Electricité.

seen ; D, a small capsule of platinum containing distilled water, in which the evaporation takes place that produces the cold. The bars in this pile are thrown into the form of a crown that they may support the platinum capsule, and be placed in con-, tact with it. When it is brought into action, it must be freely exposed to the air subjected to experiment, but protected carefully from the influence of currents by the receiver, and from the radiation of external objects by covering the receiver with paper. It is obvious that the superior extremities, on which the capsule is placed in taking observations, must be exposed to a reduction of temperature according to the amount of evaporation, when the galvanometer will be proportionally affected.*

PART III.

CHAP. I.—THE LABORATORY—MISCELLANEOUS APPARATUS.

2793. Most of the apparatus required for performing the different experiments detailed in this work having been described along with the experiments themselves, it will be sufficient in this chapter to make some general observations on the laboratory, and on miscellaneous apparatus that may be useful to the beginner.

2794. " The Laboratory" is a term used in such an extreme variety of significations, that it is impossible to give any rules in

* In Professor Jameson's Journal for October 1838, &c. the reader who may be more particularly interested in the history of atmospheric electricity and the phenomena of thunder and lightning, will find a very full account of this subject by Arago.
    The electric telegraph presents a beautiful practical application of this science. The first was introduced at St Petersburgh ; it has also been constructed of various forms at Berlin. In this country, Professor Wheatstone and Mr Alexander have been engaged in the same subject, and a very elaborate and ingenious telegraph has been constructed by Mr Ponton, a model of which may be seen at the Soc. of Arts for Scotland.

reference to a subject of such extent and importance which will not require to be modified in almost every case, according to the views of the operator and the time and the expense he may intend to devote to it. The student whose time is much occupied with many different branches of science, may content himself by purchasing fifty or sixty specimens of chemicals, including half a dozen of phials with acids and alkalis, and a test tube, and with these the (whole cost of which may not exceed between five and ten shillings), by operating on flat glass and slips of paper, with the assistance of a common lamp or candle and an ordinary fire, he may perform many thousands of test experiments, such as he may have seen on the larger scale in the lecture room, and become thoroughly familiar with the leading action of chemical action, by renewing again and again these experimental illustrations at his own convenience at home.

2795. The small museums with flat glass, prepared by Mr Macfarlane, consisting of about 60 specimens, with bottles containing the most important acids and alkalis, are extremely useful in enabling the student, who has neither time nor opportunity to operate with more extensive apparatus, to make himself familiar with a wide range of chemical phenomena.

2796. The following list of materials and apparatus may be useful to those proposing to commence a series of experiments by themselves :—

Sulphuric, Nitric, and Muriatic Acids; solution of Potassa and Ammonia,—all these must be kept in stoppled phials.

Sulphur.	* Hydrosulphuret of Ammonia.
Phosphorus.	* Chloride of Lime.
Iodine.	* Muriate of Lime.
* Fused Potassa.	Sulphate of Lime.
* Carbonate of Potassa.	Phosphate of Lime.
Bicarbonate of Potassa.	Phosphuret of Calcium.
' Sulphate of Potassa.	Fluoride of Calcium.
Nitrate of Potassa.	Sulphate of Baryta.
Chlorate of Potassa.	* Nitrate of Baryta.
Bitartrate of Potassa.	Sulphuret of Barium.
* Ferroprussiate of Potassa.	Strontia.
* Bichromate of Potassa.	* Muriate of Strontia.
* Iodide of Potassium.	Magnesia.
* Silicated Potassa.	Sulphate of Magnesia.
* Carbonate of Soda.	* Alum.
Bicarbonate of Soda.	Silica.
e Phosphate of Soda.	Iron.
* Oxalate of Ammonia.	Oxide of Iron.
* Carbonate of Ammonia.	Peroxide of Iron.

* Sulphate of Iron.
* Permuriate of Iron.
  Lead.
  Sulphuret of Lead.
  Litharge.
  Red Oxide of Lead.
  Carbonate of Lead.
* Acetate of Lead.
* Nitrate of Lead.
  Ore of Cobalt (Arsenuret),
  Tin.
  Bismuth.
  Antimony.
  Sulphuret of Antimony.
  Copper.
* Sulphate of Copper.

* Nitrate of Copper.
  Zinc.
  Oxide of Zinc.
  Arsenious Acid.
  Sulphuret of Arsenic.
  Binoxide of Manganese.
  Mercury.
  Binoxide of Mercury.
* Bichloride of Mercury.
  Bisulphuret of Mercury.
  Bicyanide of Mercury.
* Nitrate of Silver.
* Bichloride of Platinum.
* Terchloride of Gold.
* Tincture of Galls.

* Oxalic, Tartaric, and Benzoic Acids.
  Cabbage, Turmeric, and Litmus Test-papers ; Filtering Paper.
  Chalk or Marble, Sulphuret of Iron, and Borax, may be provided in larger quantities.

Pneumatic Trough with Shelf.
Pneumatic and Precipitate Jars, with Tin Trays.
Tube Retort, Receiver, and Funnel.
Basin for evaporating.
Watch Glasses.
Test-Tubes.
Pipettes.
Bottle and Bent Tube.
Spirit-Lamp.
Glass Funnel.
Slips of Glass for Solution, Evaporation, Crystallization, Fusion, and Testing.
Apparatus for instantaneous Light.

Retort, Stand, and Ring.
Cupped Steel Block with Steel Bar.
Triangular Supports made of Wires of different Metals.
Crucibles.
Blow-pipe.
Blowpipe Lamp.
Blow-pipe Cups.
Brass Mould for making them.
Platinum Wire.
Supports for Candles, Sulphur, Phosphorus, Test-Tubes.
Iron-Wire, Slips of Copper and Tin.
Phials, Test-Tubes.

2797. Paper dipped in different fluids and then dried is well adapted for illustrating a great variety of chemical phenomena. Dip different slips of paper into solutions of nitre, nitrate of lead, and nitrate of copper; dry them and set them on fire, so

*An * (asterisk) indicates that the substance before which it is placed should be kept in solution as well as in the solid form. Phials capable of holding from one dram to two or three. ounces are sufficiently large for holding the tests. Boxes containing the materials, &c. represented above, should not cost more than about three pounds : when of the larger size, and intended for introductory courses in schools and academies, from five to ten pounds may be expended upon them.

as to burn without flame ; carbonate of potassa, highly alkaline. is produced with the first, metallic lead and copper with the others, the copper immediately attracting oxygen, and assumes a dull appearance.

2798. Take other portions of paper, put upon them a number of drops of any solutions to be tested, and apply the different tests. Cartridge paper does best for this purpose. Sometimes the paper is dyed in a metallic solution, and the tests applied by dipping a pen in them, and writing with it on the paper.

2799. But when a laboratory is to be provided on a larger scale, either for teaching the practice of chemistry, or for those whose leisure, opportunities, or professional engagements lead them to enter upon an extended and elaborate course of experiments, then there is no limit to its extent, nor to the various arrangements that may be adopted to give power and facility in conducting chemical operations. Each individual, accordingly, should consider well the extent to which he proposes to experiment, and from the illustrations already given, and those which will be added at present and in subsequent parts of this work, little difficulty will be experienced in arranging a plan suited to the peculiar circumstances of each individual case.

2800. Whenever it is possible, different apartments should be attached to the laboratory, more especially one for delicate instruments, and for weighing the results of analytical investigations, another for cleaning the apparatus employed, and a third for materials, or at least for a large stock of those that may tend to produce acrid fumes.

2801. One principal fire-place for supplying fuel already kindled, conducting ordinary operations requiring no great elevation of temperature, for heating water and a sand-bath, is of great use. One furnace also should be provided, capable of producing an intense heat. The annexed Figure (417) gives a sketch of a chimney surrounded by four furnaces, any of which may be arranged, so as to be used as an open fire-place, if the apertures leading to the others be closed ; and, having tried a number of chimneys of this form, I am satisfied that they are extremely well adapted for a great variety of chemical operations. The vent is only ten inches square, and from fifteen to twenty feet high; and, one furnace being fitted up, it may be used for heating a tube traversing it (B), for crucible operations (C), for a

Fig. 417.
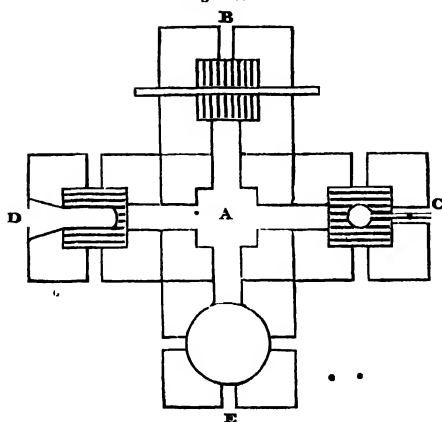
muffle D, such as is used in cupellation, and for a boiler or still (E). See *Furnaces* and *Fire-places*, pages 144 to 154, and, more particularly, Figs. 131, 132. With a chimney no larger than that shewn in 417, and with four furnaces in full operation, the area of each being a cube of ten inches, all ordinary metals may be quickly melted, and a button of metallic iron procured with facility from the ore when treated in the manner described under iron.

2802. Fig. 418 represents a similar chimney on a smaller scale,

Fig. 418.
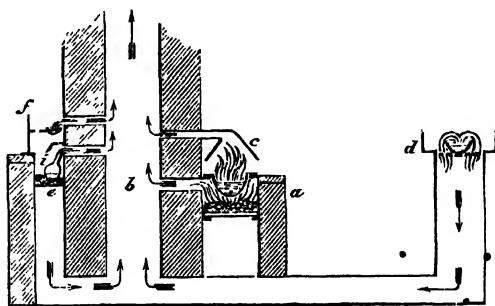
which will give a better idea of the arrangements that may be connected with it, more especially for ventilation. *a* is the furnace heating any mixture in an iron pot, from which offensive fumes are discharged ; *b*, the chimney ; *c*, a hood by which fumes are collected; *e*, a small fire-place with a descending flue, in which charcoal principally may be used, with a flask containing a liquid boiling, and discharging acrid vapours ; *f*, an evaporating basin ; *d*, another evaporating basin placed over a descending flue. Where the apertures leading into one chimney are very numerous, arrangements should be made for plugging up those not in use, that the others may act more powerfully.

2803. Where a very high temperature is frequently required,

a blast furnace is used. It is supplied with air solely by a pair of double bellows or by a fanner. For many purposes nothing will be found so convenient as a smith's forge, and in every village there are masons who can build them. When the fuel employed gives but a small quantity of ashes, the body of the furnace may have a form similar to Mr Aikin's furnace, and be built of fire-bricks joined by Stourbridge clay, or some other fire-clay, allowing a free opening above for the escape of air. If, however, the furnace is not to be used solely for crucible operations, but to be employed in other processes where a considerable quantity of scoriæ may be melted, the opening for the bellows had better then be made at the side, and a little higher, that these may be run off by an aperture below when necessary.

Fig. 419.
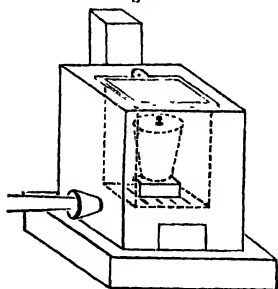
In many cases a sufficient increase of temperature for experiments on the small scale may be easily procured, by converting a common furnace into a temporary blast furnace in the manner represented in the figure. An additional opening is made below the grating for the nozzle connected with a pair of double bellows; it is scarcely necessary to mention, that this aperture must be completely closed, when the furnace is in use, by the nozzle of the bellows, and the furnace door must also be shut, closing any small opening afterwards with a little clay. See page 289.

2804. Instead of constructing a blast furnace of fire-bricks,

Fig. 420.
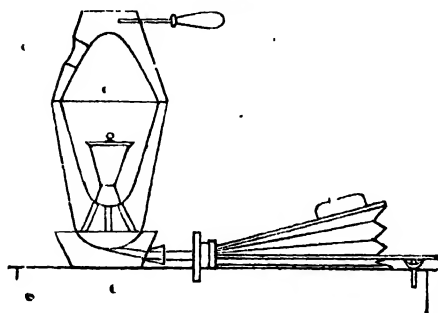
Mr Aikin contrived a very convenient one which may be made of three large crucibles or melting-pots; the lower part of the first one serves as a resting-place for the body of the furnace, and a hole drilled in it admits the nozzle of the bellows. A larger portion of another crucible is placed above this, and forms the body of the furnace, four or five holes being drilled in it to admit

the air; and the upper part is a similar portion of the third crucible with a large hole cut at the side to allow the flame and gaseous matter to escape. Blast-furnaces of this kind are usually made about 16 or 18 inches deep, from the bottom of the lower part to the top of the cover, and their greatest diameter 7 or 8 inches. The cover is not absolutely necessary, though it is certainly better to use it, as it protects the eyes from the light. .

2805. No luting is required for this furnace; a small pair of double bellows will be found quite sufficient, and when it is well managed, which a little practice will soon enable the beginner to do, a thick piece of cast iron may be easily fused in it. The best kind of fuel for a furnace of this kind is coke or red-hot cinders taken from a common fire; they should be free from dust and ashes, in small pieces, and as nearly of one size as can be conveniently had. The bellows should be fixed to a strong frame, and the crucible furnace must be adjusted to a corresponding height.

2806. A sand-bath will be found extremely convenient where a great number of experiments are performed; but as there are not many students who have an opportunity of constructing a proper sand-bath furnace, I shall now describe a method of arranging a common fire-place, which will be found very useful by those who can only have the use of a common apartment for carrying on their experiments.

2807. Instead of putting in a grate of the usual form, let one

Fig. 421.
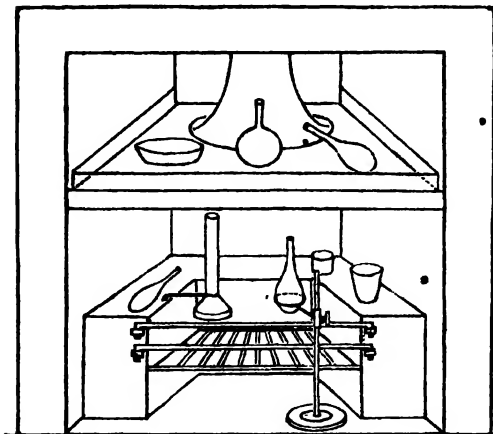
be built of brick of the form, represented in the figure (Fig. 421.) Though no iron-work is absolutely required for the grate itself, except the grating to support the fuel, which should be proportioned to the size of the fire-place, and two or three bars which may be placed in front so as to rest

in grooves left for the purpose, from which they may be easily
taken out by a pair of tongs if required ; still it will be found much
better to have the principal parts made of iron, and built in with
fire-brick. A large and powerful fire may be kindled in this fire-
place, which will not only be easily accessible and very conve-
nient for a great number of common furnace operations, but
advantage may also be taken of it to heat a sand-bath placed
above it. For this purpose an iron plate must be fixed in the
chimney in the manner represented ; a funnel-pipe conveying the
smoke from the fire below into the vent, which ought to be closed
in on every side by a thin plate of sheet-iron, so that no smoke
can pass into the vent except through the funnel-pipe connected
with the sand-bath. In this manner, a constant draught is
maintained, and the fire burns well ; and though the hottest
part of the sand-bath seldom reaches a temperature above 500°
or 600°, still this is more than sufficient for the greater number
of operations where a moderately hot sand-bath is required, and
by placing the same substance on different parts of the plate, it
may be exposed to the action of various degrees of heat. The
sand on the plate need not be more than an inch and a half
deep. and a small piece of sheet-iron should be fixed in front to
prevent any of the sand from falling off, and any hot air from
escaping below ; it will be better also to place the plate in an
inclined position. Such a sand-bath will be found particularly
useful for digestion, slow evaporation, and a variety of other
operations where a moderate heat is required. When disagree-
able fumes are disengaged during any process, the vessel con-
taining the materials from which they arise may often be placed
under the sand-bath, when they will be carried up into the vent ;
coated vessels may be dried slowly by placing them at the side,
and a crucible placed in the fire may be exposed to a consider-
able heat by placing a chimney over that part of the fire in which
it may be put. I am not aware of any plan which will render
a common fire-place so generally useful for performing a great
number of experiments.

2808. In converting a common fire-place into a furnace of
this description, it is necessary to examine carefully the flooring
and the hearth-stone in case of accident from fire. In many
cases, the arrangements for the fire-place are very dangerous,
the hearth-stone being often made of Arbroath pavement, or
of some other stone that cracks on exposure to heat, red-hot

cinders fall through these cracks and inflame the support of the flooring which is often placed immediately below. Many fires have been traced to this cause, and in some instances solely to the heat communicated by the ashes to the hearth-stone, and from it to the wood below. No practice can be more dangerous than that of supporting by wood any thing which must be necessarily exposed for a long time to such an elevation of temperature. A sufficient hearth-stone should in all such cases be immediately substituted, building it in the wall, and supporting it when necessary by a brick arch thrown between the wall and one of the rafters of the floor at some distance from the fire.

Besides furnaces of different kinds which the student can procure according to the series of operations he intends to perform, he should be provided with two or three hundred bricks of different sizes and figures, with which, if he be an active experimenter, he will soon be able to construct a number of different temporary furnaces as they may be required. A ball of well worked fire-clay will also be found of great use, and save much trouble ; it should be kept in a box made for the purpose, or wrapped round with a moist cloth, pouring a little water on it from time to time, to prevent it from getting dry.

2809. In making arrangements for carrying on a series of experiments, it is of great importance to attend to the VENTILATION of the apartment in which they are conducted. All experiments, during which noxious fumes are disengaged, should be made under a hood or chimney, so that they may be immediately removed. A tube, one extremity of which is introduced into the chimney of a heated furnace, will draw away a large quantity of vapour produced in any experiment, when the materials are brought near the other extremity. See pages 148 and 151. Arrangements should also be provided, not only for removing at once offensive fumes, but also for clearing quickly the air of the whole apartment by large windows or apertures in the ceiling, when this may be necessary.

Where many experiments with fuming acids and other offensive materials are, performed, the sand-bath is often provided with a glass or other cover, and ventilated by connecting it with a chimney.

2810. In many cases a small temporary sand-bath may be made by exposing any thin vessel of sheet-iron (Fig. 422) to

the flame of a lamp, or to the heat produced by a few pieces of charcoal in a state of combustion, the sand B supporting a test tube C, which may contain a liquid, if necessary, for communicating heat to another tube D. The figure represents the apparatus of full size.

2811. A variety of tongs and pincers, and of straight and bent iron-rods, will be found necessary for a number of experiments and processes. The annexed figures shew one or two of the most convenient forms of these that have not been already described.
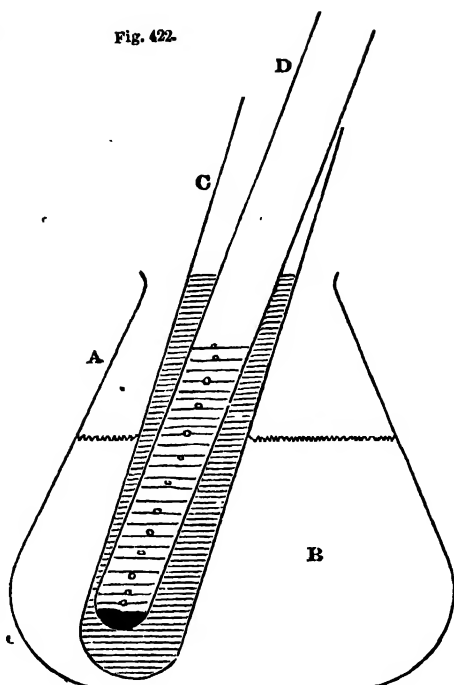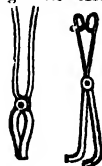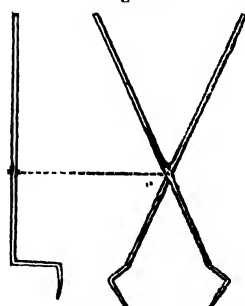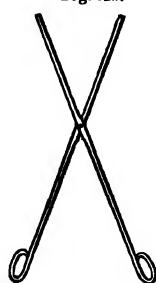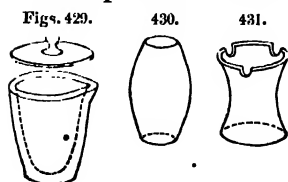
Fig. 422.

2812. For all ordinary purposes, HESSIAN CRUCIBLES will be found most convenient, as they resist a very high temperature, and are not so apt to be fluxed when heated with saline

substances as any of the crucibles made in this country, with the exception of Cornish crucibles, which are not easily pro-

Figs. 429.   430.   431.

cured. Crucibles are made of a great variety of shapes; the triangular form of the Hessian crucible is well known, and the annexed figures represent the other forms of which they are usually made.

Crucibles should never be exposed suddenly either to heat or cold, as they are then very frequently cracked. When they are removed from a hot furnace, they ought to be placed on a piece of charred wood, or on a few cinders kept for the purpose. In many cases, a piece of iron-wire, rather thinner than a common quill, and coiled in the manner shewn in the figure, will be found very convenient for supporting Hessian crucibles; the few points of contact between the crucible and the stand prevent it from being broken. A piece of clay or lead may be fixed to the lower part.

Fig. 432.

BLACK-LEAD crucibles may be procured of all sizes, as they are much employed in the arts; they are made of a mixture of plumbago and clay, they may be used in general more frequently than Hessian crucibles, as they are not so liable to crack; they are destroyed, however, by long exposure to a current of heated air, and by nitre and some other saline substances. Crucibles made of Wedgwood's ware are very compact, and should be placed in a common crucible when they are used, as they are apt to crack.

A small platinum crucible will be found necessary for a number of experiments, and is used principally for the purpose of fusing substances with potassa which contain a considerable quantity of silica, or for heating precipitates to redness analytical operations. They may be heated in the manner represented under silica, page 280, in the flame produced by a mixture of gas and air, page 163, Fig. 152, or in an argand spirit of wine lamp, Fig. 433, according to the temperature required. Fig. 434 represents a convenient mode of supporting the platinum crucible. See platinum crucible, page 279.

2813. Where a very moderate heat is required, the common spirit of wine lamp may be used. In Fig. 435 it is seen with
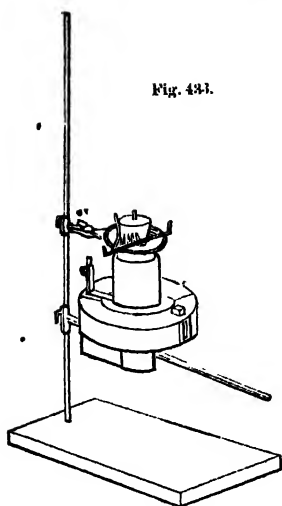
Fig. 433.
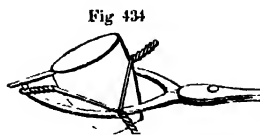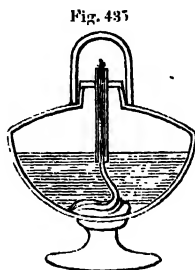
Fig 434

Fig. 435

a cover, much employed for preventing the loss of spirit of wine
by evaporation when it is not in use. Pyroxilic spirit may be
substituted for spirit of wine, as it burns without producing
smoke.

2814. Cast-iron crucibles may be easily procured at any iron-
foundry, and a common crucible may be given as a pattern to
make a mould to cast it in.

2815. Evaporating vessels may be made of glass, Wedgwood's
ware, or metal. Vessels made of the first kinds of ware (those
from Berlin are perhaps the best that are made) are generally
employed for chemical purposes, as they are not so liable to be
acted on as metallic vessels; in evaporating large quantities of
liquids, however, which do not act upon metallic vessels, they
Fig. 436.   should always be preferred. They are usually made
broad and shallow, that an extensive surface of liquid
may be exposed to heat during evaporation.

2816. Instead of flat evaporating glass-vessels, Florence flasks
and wine-flasks may be substituted with advantage in a number
of processes; they will be found preferable to flasks made of
flint-glass, as they are extremely thin, bear sudden alterations
of temperature much better, and are not nearly so liable to be
broken in the ordinary course of chemical operations.

Small flasks made of very thin glass, about two or three

inches in diameter, and of the form represented in the figure,

Fig. 437.

are very useful in a number of chemical operations where it is necessary to expose a liquid for a short time to a boiling temperature ; though made of flint-glass, they may be put with safety on the cinders of a small chauffer if they are half full of the liquid. They may be used also for ascertaining the quantity of solid matter in a given weight of a saline solution, evaporating it slowly on a sand-bath.

2817. When a solid is to be digested for a long time in a liquid, flasks with a long neck (Fig. 438) are sometimes preferred ; but for ordinary purposes they may be made of a taper or globular shape, as in Fig. 439, and Fig. 440.

Fig. 438.　Fig. 439.　Fig. 440.

2818. All acid and corrosive liquids should be preserved in bottles with stopples carefully ground, and for particular substances, as hydrofluoric acid, special apparatus is required, viz. a leaden or a silver bottle. All bodies also extremely prone to oxidate should be carefully luted so as to exclude the external air, and some, as potassium, must also be surrounded with the finest naphtha.

Fig. 441.　Fig. 443.　Fig. 442.
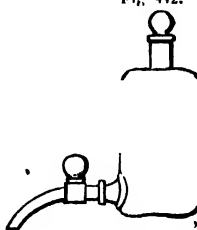
2819. Figs. 441, 442, represent bottles much used for holding large quantities of liquids ; the latter is also used for separating fluids that may be mechanically mingled, pouring out the heavier by the spout while the other is left. Where many tests are continually required, a small case, Fig. 443, for the more important, will be found very useful.

2820. In the process of distillation, it is often necessary to prolong the neck of a retort before connecting it with a receiver,

that the different parts of the apparatus may be conveniently arranged, or to facilitate the condensation of the vapour ; this is usually effected by means of a glass-tube, sometimes blown into a globular shape in the centre, one extremity fitting or being luted to the beak of the retort, while the other is introduced into the receiver.

This tube is termed an *Adopter*, and the method of adjusting it will be readily understood from Fig. 444.

Fig. 444.
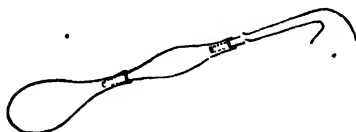
Fig. 445.
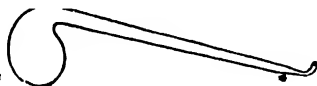
2821. In preparing gases at the mercurial trough, which must often be collected in very small jars, it will sometimes be found convenient to draw out the beak of the retort in the manner shewn in the figure, making it smaller at the same time that it may be readily introduced into a small aperture.

2822. In distilling liquids that boil very suddenly and unequally, and require a very high temperature, an arrangement,

Fig. 446.
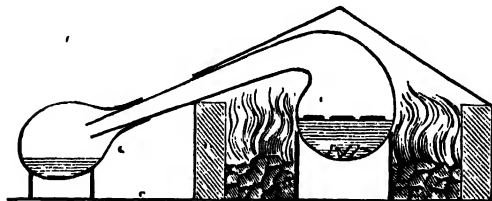
Fig. 446, such as has been proposed by Berzelius, for distilling aqueous sulphuric acid, is very convenient. The retort rests upon an iron ring and is protected by a sheet-iron cover from the air. Small quantities of charcoal are kindled in succession around it till a proper temperature is attained. Fragments of platinum foil, or small glass tubes hermetically sealed so as to float upon the surface of the oil of vitriol, are very useful in preventing violent ebullition.

2823. Fig. 447 represents Mitscherlich's mode of preparing ether described in pages 527, 528. A stream of alcohol mixed with water flows continuously into the acid placed in the flask, the quantity being so adjusted as to maintain a constant temperature, which is indicated by the thermometer. The products pass over to the receiver and are cooled by a variety
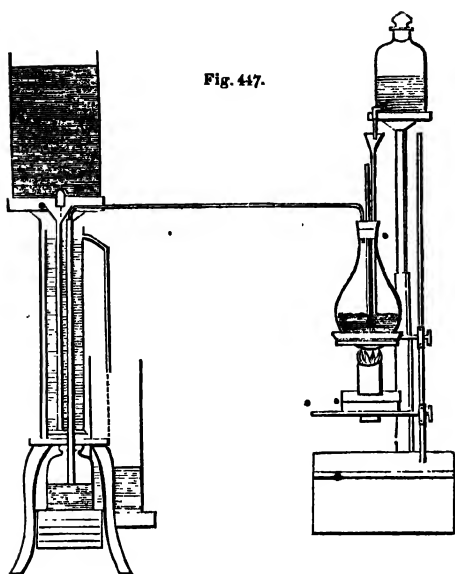
Fig. 447.

of Liebig's receiver, which is supplied with a constant stream of cold water from a cistern above it.

2824. Fig. 448 gives a different view of Liebig's receiver. It consists essentially of a glass tube ff, to which a tube from any distilling apparatus may be attached, and of a cup containing cold water, $c c$, which may be made of japanned tinned iron or of copper; $a, b, c c, d$ represent the course of the water by which it is continually supplied, so that it is very effectual in condensing completely any vapours that may be led into f.

Fig. 448.
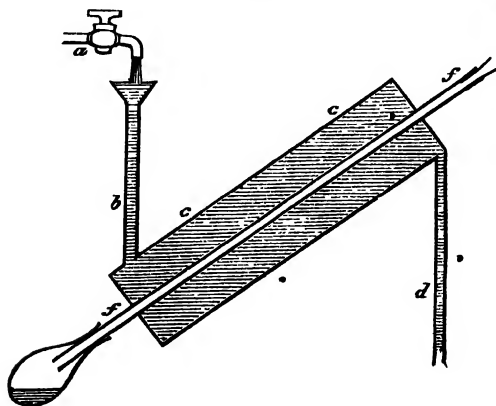
Fig. 449.
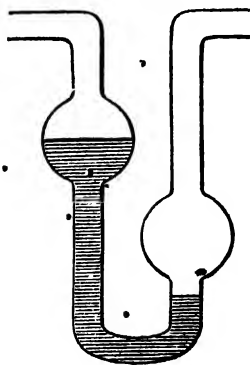
2825. The tubular balled receiver of Mr Davy, Fig. 449, is very convenient in many cases where an absorbable gas is to be passed through a liquid.

2826. Fig. 450 represents the form of a bent tube which is

Fig. 450. frequently employed in the process of distillation and in a number of other operations, where it is necessary to pour small quantities of liquid at a time into a vessel, without shifting the apparatus with which it is connected, or taking out any stopple that might expose its contents to the action of the air. The liquid that remains in part of the tube acts as a valve, which prevents the ingress or egress of air, but does not present any obstacle to the introduction of more liquid. In operating with corrosive liquids, instead of fitting it to the tubulure of glass-vessels with a cork, it must be fixed in its place with a proper cement, or the tube may be made thicker at its lower extremity, and ground to the tubulure in the same manner as a stopple.
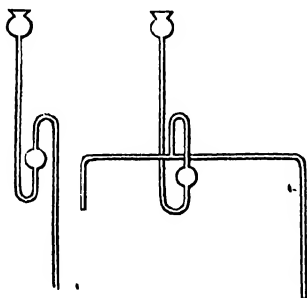
2827. Fig. 451 represents a tube such as is frequently attached to the tubulure of a retort where there may be danger of condensation, a small quantity of mercury, or of some other liquid, being introduced so as to occupy the lower curve and prevent the too ready ingress or egress of air.

Fig. 451   Fig. 452.

2828. Fig. 452 represents another form of safety tube interposed between vessels where there may be danger of condensation.

2829. For subliming benzoic acid, chloride and bichloride of mercury, and a number of other substances, a glass-vessel of the form represented by Fig. 299, page 683, will be found very useful. It is usually termed an alembic, and consists of two parts ; the materials to be sublimed are put into the lower part, and the upper part is ground to it or joined with a proper cement. The small tube proceeding from the lower part of the capital carries off any watery vapour that may be condensed, which would otherwise drop into the lower part and break it. When the alembic is used for the sublimation of benzoic acid or of any other substance, where only a very gentle heat is required, the heat may be applied in the usual way by a chauffer, supporting it by a retort stand. When a higher temperature is necessary, it may be placed in a sand-bath.

2830. In many cases, two crucibles may be employed for a

similar purpose, as in the sublimation of metallic arsenic from

Fig. 453.

a mixture of arsenious acid and charcoal. The mixture must be put into the larger crucible, which may be placed in a sand-bath and exposed to a strong heat, inverting the other crucible and luting it to the first; a small aperture must be left at the edge for the escape of gaseous matter, or a hole may be bored in the smaller crucible, and a glass tube inserted in it.
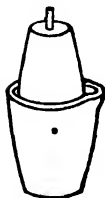
2831. For separating liquids of different specific gravities, which have no chemical action on each other, a glass vessel

Fig. 454.

termed a Separator is generally employed, consisting of a funnel-shaped ball open at the top, and terminating in a long tube (Fig. 454). A funnel with a long stem does very well for the same purpose, allowing the liquid to pass slowly through, after filling the vessel, and leaving it till at last the lighter portion has collected above, transferring it to another vessel as the last part of the heavier portion descends in the stem. See also Fig. 438, page 785.

2832. An assortment of glass-funnels of different sizes will be found necessary where many experiments are performed; they are used not only for pouring liquids from one vessel to another, but also for supporting filters in the process of filtration.

2833. Filters are usually made of unsized paper, doubling a

Fig. 455.

square piece by two opposite corners, so as to make it have a triangular shape, and then folding it alternately outwards and inwards from the centre, till it assumes the appearance represented in the figure on blowing upon it so as to separate the opposite sides, and cutting off the projecting points.

2834. Filtering papers should be selected with much care. They are often charged with an extreme variety of impurities, more especially alum, sulphate of lime, and metallic substances, which render them unfit for various purposes. These may, in general, be detected by boiling the paper in water acidulated with muriatic acid, or the paper may be reduced completely to ashes by burning it, and the residuum examined by proper tests.

2835. In all analytical experiments, the nature of the filtering paper should form a principal object of attention. In general,

an additional filter is employed where one alone is absolutely necessary for filtration; and this being subjected to the same treatment as the first, may be used as a counterpoise for it in weighing precipitates dried upon the filter.

2836. Fig. 456 represents the general arrangement adopted in filtration. Fig. 457, a very simple form of retort-stand, *a b*, with an evaporating basin *c*, heated by a spirit-lamp *d*, made with a common phial; *f* is a filter and funnel, the filter being made simply by folding a square piece of paper into four parts, and then opening it, so as to have three folds on one side, and one on the other.
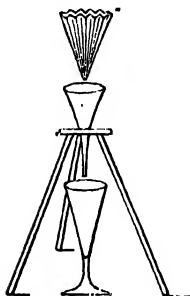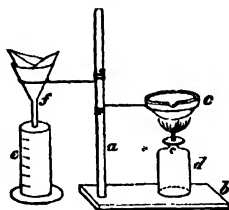
Fig. 456.

Fig. 457

Fig. 458.   Fig. 459.   Fig. 460.
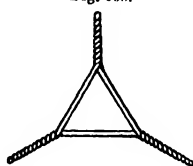
2837. Fig. 458 shews a liquid filtering into a thin glass, which may be heated on sand or in a hot press, so as to be maintained warm during filtration. Fig. 459 represents a mode of filtration without a funnel, which may be occasionally resorted to with advantage where a minute quantity only of a fluid is required. Fig. 460 is a triangular support, which may be made of glass, porcelain, and occasionally of metallic wires, where a liquid is filtered without a funnel.

Fig. 461.

2838. Precipitates left on a filter are washed merely by pouring water upon them till it passes through without taking up any soluble matter. A pipette of the form seen in Fig. 461, will be found very useful in separating precipitates from filters after they have been washed, and while they are still moist, filling it with water and then blowing a small stream of this fluid through the extremity till

Fig. 462.

the precipitate is washed into a vessel placed below, after which the water may be dissipated by heat. Pipettes are also extremely useful for pouring or dropping small quantities of liquid upon any substance, as they can be easily made to terminate in a tube suffi•ciently large to give a slender stream, or drawn out into a fine.capillary bore in the flame of a spirit-lamp. It is not necessary for most purposes to have a ball blown in the centre ; a piece of a common test-tube, about 12 or 18 inches long, held in the flame of the lamp till it is softened and then drawn out gently, will give two pipettes on breaking it through the middle, which will be found quite sufficient for all ordinary operations in which they are required.

2839. A small glass syringe, Fig. 462, is still more convenient for cleaning filters than a pipette.

2840. When a precipitate is to be washed upon a filter, water must be allowed to drop upon it until it ceases to be affected by tests as it escapes. A flask is often inverted upon a glass precipitate, as in Fig. 463, when it is to be washed, supplying water slowly as it sinks below the level of the liquid in the funnel.

2841. Instead of using filters, precipitates are very conveniently washed by repeated effusion with water and decantation, where time is not an object of importance.

2842. If any small portions of sand or other solid adhere to a flask or jar, they are most conveniently removed by filling it with water, and then inverting it in a basin, as in Fig. 464.

Fig. 463.   Fig. 464.

2842. In addition to the glass funnels required for filtering a number of liquids and other purposes, a square wooden frame with a brass point at each corner for fixing a woollen or linen cloth is frequently required, especially in filtering bulky precipitates, as the precipitated oxide of anti-
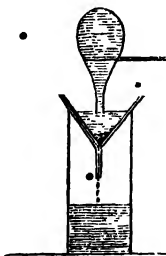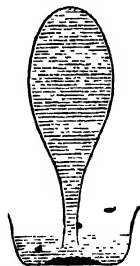
Fig. 465.
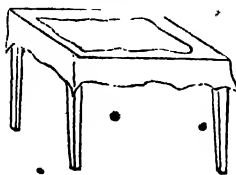
mony, or the mixture of quina and sulphate of lime obtained on adding lime to the acid decoction of yellow bark.

2843. Instead of pouring off a clear liquid, it is often more convenient to run it off by a syphon. This is merely a bent tube which is filled previously with water or any other liquid, and on introducing the shorter limb into the vessel containing the liquid to be drawn off and under its surface, it will rise in the syphon and pass out by the other extremity. Syphons are very useful in chemical operations, and are made of a great variety of shapes and materials, though the principle on which they are constructed is the same in all. A very simple experiment, which will render the student familiar with the method of using them, may be performed by filling a plain syphon (made with both limbs of the same size and in the form of the letter U) with water, and putting each extremity into a jar of water at the same time. If the water be at the same height in both jars, none will pass from the one to the other though the syphon tube should be perfectly full ; if one of the jars be lifted up with the syphon in it, water will immediately flow from it to the other, and by alternately raising or depressing one of them, the water may be made to pass in either direction through the syphon, always, however, from the jar in which it is at a higher level to the other, and ceasing to flow whenever the liquid acquires the same level in both.

Fig. 466.

2844. Fig. 467 represents a form of syphon very useful in many cases; the shorter extremity being dipped into the liquid to be drawn off, the other is closed for a moment, and by sucking out air by *a b* it is immediately put in action.

Fig. 467.
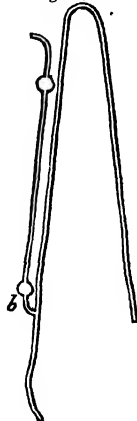
2845. Phillips' precipitate glasses will be found very useful for allowing small precipitates to be deposited, as, from their form, little can adhere to the sides. When made of thin glass, they may be used for a number of operations in the same manner as a Florence flask, and liquids may be heated in them by placing them on a sand-bath.

Fig. 468.

2846. Flasks and funnels, and a number of other pieces of

apparatus, being usually supported on retort-stands or rings when in use, and many requiring to be kept for some time, several shelves should be fitted up with a number of holes of different sizes and at different distances from each other, so that they may be set aside where they will not occasion any incon-

Fig. 469.
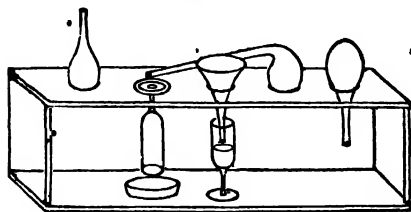
venience. When this cannot be done, wooden stands of different sizes may be made to serve the same purpose. The annexed figure represents one of the simplest methods of constructing them.

2847. In places where a great number of experiments with gases are made, large quantities of those that are most in use should be made at a time, and stored in convenient vessels from which a supply may be easily procured as it is required; the gasometers which have been already described may be used occasionally for this purpose, when the gas is not absorbed by water; but the apparatus employed by Dr Hope, and which he has permitted me to describe, will be found much more convenient. It consists of a large oil of vitriol bottle, with a brass cap cemented to the mouth, in which two tubes with stop-cocks are fitted, water being introduced and forced out again when necessary by one, and gas by the other. In the

Fig. 470.
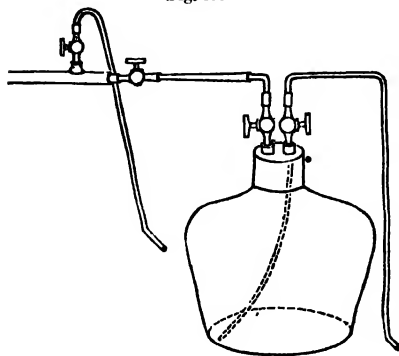
figure, it is represented in connexion with the extremity of a bent gun-barrel fixed in an iron retort in which oxygen is prepared from the peroxide of manganese by heating it in a furnace. It is obvious, that a large bottle of this kind could scarcely be moved when full of water without being broken, unless properly supported, and nothing does better for this than a tub made

to fit the bottle, covering the bottom for the depth of an inch or two with saw-dust, and packing the space between the bottle

and the sides with the same material. This will allow it to be moved easily from one place to another, and it has not been represented in this manner in the figure, merely that the arrangement of the tubes connected with it may be seen more distinctly.

2848. To explain the method of using it, I shall now describe the manner in which it is filled with oxygen gas. After filling it with water, a bent tube is to be connected with the gun-barrel by a flexible leaden tube, about two or three feet in length, though represented much smaller in proportion to the size of the rest of the apparatus in the figure; but no gas is to be allowed to pass into it unless it is sufficiently pure, the stop-cock at the extremity of the gun-barrel being kept shut, while the other one is to be opened; and the gas that is disengaged at first is to be collected by means of a bent tube fitted to it, in small bottles over a pneumatic trough, so that its state of purity may be easily ascertained. When it is thought proper to commence collecting it, this stop-cock is to be shut and the other must be opened, so that the oxygen will now pass on to the gasometer, entering by one of the first mentioned tubes. Here it will press upon the surface of the water, which will be forced up through the tube seen in the interior of the bottle, continuous with the second stop-cock attached directly to the cap; and, another bent tube being then placed over it, a syphon is formed, through which the water will continue to flow as long as any gas is disengaged. By using a large quantity of materials at a time, several bottles may be filled successively in this manner without undoing any part of the apparatus, except the leaden pipe that connects them directly with the gun-barrel. One bottle may be detached and replaced by another in a few seconds when every thing is properly adjusted; and, if a longer time should be required, a few jars of oxygen may be collected from the tube attached to the stop-cock fixed to the upper part of the gun-barrel, or that tube may be adjusted to the second bottle gasometer, while the first one is being filled. The stop-cocks attached to the brass cap of these gasometers must be shut as the tubes connected with them are detached.

2849. Again, Fig. 471 shews the method in which the gas is transferred from a gasometer of this kind when required for use. The syphon being detached, a thin funnel is placed above

Fig. 471.
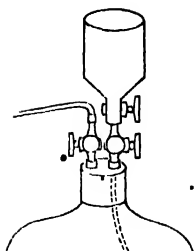
the stop-cock to which it was previously fixed ; and it is evident, that, on pouring in water, and opening the stop-cocks, it will descend through the tube in the interior of the bottle, and force the oxygen out at the other stop-cock by which it had entered ; by connecting a flexible tube, accordingly, with this stop-cock, and pouring water into the funnel, the gas may be easily transferred to other vessels. It is in the same manner also that the air is expelled, and the gasometer filled with water, before connecting it with the oxygen gas apparatus.

2850. A bladder is often filled with gas for temporary experiments, in the manner shewn in Fig. 472, and if the gas be re-

Fig. 472.
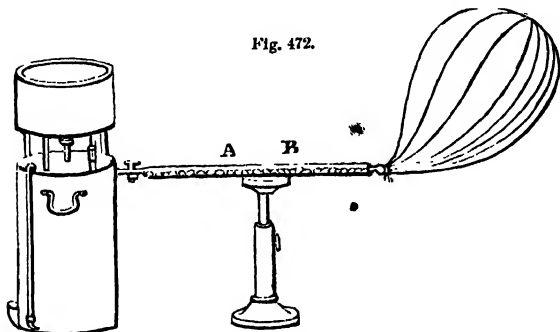
quired free from moisture, it is dried by passing it slowly through a tube filled with fragments of chloride of calcium.

2851. For discharging gas in a continuous steam, an apparatus such as Fig. 473 is much used, where the gradual additions of an acid by *b* to materials already placed in the bottle *a*, is all that is necessary, as in preparing hydrogen, sulphureted hydrogen, or carbonic acid gases. The small balls, *c d*, condense any very minute drops of liquid carried up mechanically by the effervescence below.

Fig. 473.
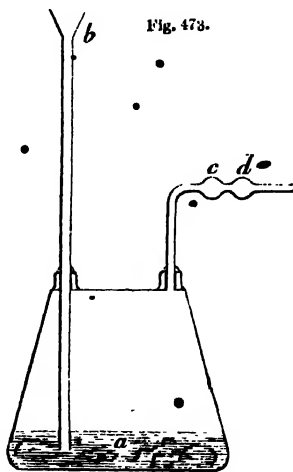
SMELLING BY TUBE—DRYING PHIALS, &c.

2852. In many operations, where it is desirable to ascertain
if any odour be produced on heating a mineral
or other substance, a fragment is introduced into
a test-tube and heated, and a small tube, open
at both ends, being inserted in the test-tube, as
in Fig. 474, the extremity without the test-tube
is introduced into one nostril, while the other is
closed by the finger. On inspiring, the air from
the subject of experiment is then drawn in
through the tube, and any odorous matter pro-
duced is often recognised, though it might have
been quite imperceptible if tried without this
arrangement. Trials of this kind should be made
cautiously, as the air is often excessively pungent as it reaches
the nostrils.

Fig. 474.

2853. It is often necessary to dry thoroughly phials, tubes,
retorts, flasks, pneumatic apparatus, jars, &c., when it may not
be possible to bring a
towel in direct con-
tact with the interior.
In such cases, mere
warmth is insufficient
to remove all the
moisture, for, though
it may disappear at
the moment, it is
gradually deposited
again from the air on
cooling. The com-
mon mode of proceed-
ing consists in clear-
ing out all acid or
other matter which
might give offensive
fumes with water, re-
moving the last ad-
hering portions of
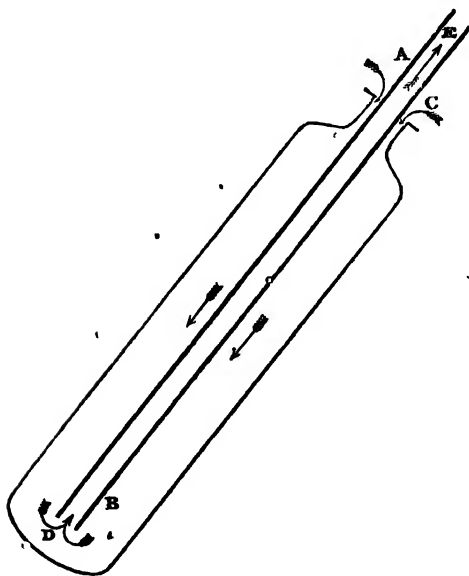
Fig. 475.

moisture by heating the apparatus, and sucking out the warm air which contains it in solution before it cools ; fresh air, free from moisture, then entering, as in Fig. 475.

2854. Where a temporary arrangement is required as a sub-stitute for a pneumatic trough, a common basin will be found suffi-cient ; two pieces of brick, marble, or of wood loaded with lead, being placed in it under water, so that the tube conveying gas may enter be-tween them, and discharge it into a jar or phial resting upon them. In Fig. 476, *b c d* represents a similar arrangement made with wood loaded with lead, so as to sink in water, the tube *a* being the extremity of any apparatus discharging gas.

Fig. 476

Fig. 477.

2855. Fig. 477 gives another view of the mercurial trough represented in page 474, shewing more parti-cularly the differences between the area above and be-low, the intermediate portion being shaded.
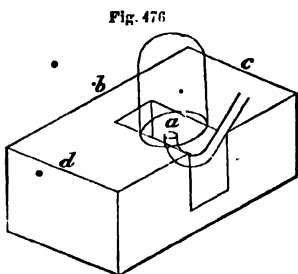
MORTARS.

2856. MORTARS of iron, brass, porcelain, glass, and agate, are continually used in preparing materials for experiments. A stone table and an anvil are very convenient where large masses are to be broken. Iron and brass mortars are desirable for breaking minerals into smaller fragments ; but it must be recollected, that they are apt to be abraded. Mortars of porcelain, Fig. 478, are in common use.

Fig. 478.

2857. The AGATE mortar is necessary in numerous experiments with minerals. A STEEL MORTAR and pestle, Fig. 479, is also required in pounding very refractory minerals, the pestle *a* being urged upon the materials at *d* by a hammer, when it descends nearly air-tight between *c* and *d*. A portion of steel being generally cor-

Fig. 479.
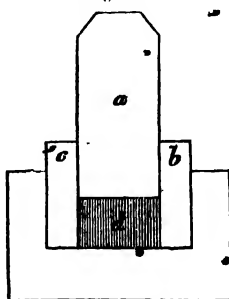
roded, and mixing with the materials, any increase of weight must be carefully noted, and allowance made for it in the progress of analysis. The pestle of the steel mortar is usually made about an inch in diameter.

2858. SMALL SLABS of iron, porcelain, marble, or slate, are very convenient in numerous operations, where powders are to be levigated or mixed with other materials.

CHAP. IX. — WEIGHTS AND MEASURES — TABLE OF THE CORRESPONDENCE BETWEEN FAHRENHEIT'S, REAUMUR'S, · AND THE CENTIGRADE THERMOMETERS.

WEIGHTS AND MEASURES.

WEIGHTS.

2859. The standard according to which the present system of weights is regulated, is the Troy brass pound, made in 1758, and now in the charge of the Clerk of the House of Commons. It contains 5760 grains.

Imperial Standard Troy Weight.

24 grains   = 1 pennyweight.
20 pennyweights = 1 ounce.
12 ounces   = 1 pound.

or,

Grains.		Pennyweights.		Ounces.		Pound.
24	=	1	=	$\frac{1}{20}$	=	$\frac{1}{240}$
480	=	20	=		=	$\frac{1}{12}$
5760	=	240	=	12	=	1

Avoirdupois Weight.

The pound avoirdupois contains 7000 grains, each of which is equal to a Troy grain, being thus heavier than the Troy pound by 1240 grains.

		1 drachm	=	27.34375 grains.
16 drachms	= 1 ounce		=	437.5
16 ounces	= 1 pound		=	7000
28 pounds	= 1 quarter		=	196000
4 quarters	= 1 cwt. or 112 lb.		=	784000
20 cwts.	= 1 ton		=	15680000

or,

Pound.		Ounces.		Drachms.		
1	=	16	=	256	=	7000 grains.
$\frac{1}{16}$		1	=	16	=	437.5
$\frac{1}{256}$	=	$\frac{1}{16}$	=	1	=	27.34375

Apothecaries' Weight.

The pound in Apothecaries' Weight is equal to the Troy pound, containing 5760 grains, but is differently subdivided.

1 pound ℔	= 12 ounces	= 5760 grains.
1 ounce ℥	= 8 drachms	= 480
1 drachm ʒ	= 3 scruples	= 60
1 scruple ℈	= 20 grains	= 20

or,

Pound.		Ounces.		Drachms.		Scruples.		Grains.
1	=	12	=	96	=	288	=	5760
$\frac{1}{12}$	=	1	=	8	=	24	=	480
$\frac{1}{96}$	=	$\frac{1}{8}$	=	1	=	3	=	60
$\frac{1}{288}$	=	$\frac{1}{24}$	=	$\frac{1}{3}$	=	1	=	20

The following tables shew the correspondence between the Troy, Avoirdupois, and Apothecaries' Weights.

Troy Weight.		Avoirdupois.			Apothecaries'.
1 pound	=	13 oz.	2 dr.	17.8125 gr.	= 1 pound.
1 ounce	=	1	1	15.15625	= 1 ounce.
1 pennyweight	=	0	0	24	= 1 scruple 4 gr.

175 pounds troy	=	144 pounds avoirdupois.
175 ounces troy	=	192 ounces avoirdupois.

Avoirdupo's.	Troy Weight.				Apothecaries'.				
1 pound	= 1 ℔	2 oz.	11 dwt.	16 gr.	= 1 ℔ 2	ʒ 4	Э 2 Э		
1 ounce	= 0	0	18	5.5	= 0	0	7	0	17.5 gr.
1 drachm	= 0	0	1	3.34375	= 0	0	0	1	7.34

Apothecaries'.	Troy Weight.		Avoirdupois.		
1 drachm =	2 dwt.	12 gr. =	0 oz.	2 dr.	5.3125
1 scruple =	0	20 =	0	0	20.

French Decimal Weight.—Gramme = 15.434 *Troy grains.*

Milligramme	=	0.015434 grains.
Centigramme	=	0.15434
Decigramme	=	1.5434
Gramme	=	15.434

MEASURES.

2860. The Imperial Standard Gallon contains ten pounds Avoirdupois weight of distilled water, weighed in air at 62° Fahr. and 30° Barom., or 12 lb. 1 ounce 16 pennyweights and 16 grains Troy, = 70,000 grains weight of distilled water. A cubic inch of distilled water weighs 252.458 grains, and the imperial gallon contains 277.274 cubic inches.

Imperial Measure.

1 quarter	=	8 bushels.
1 bushel	=	4 pecks.
1 peck	=	2 gallons.
1 gallon	=	4 quarts.
1 quart	=	2 pints.
	or,	

Distilled Water.								
Grains.	Avoird. lb.	Cub. Inch.	Pint.	Quart.	Galls.	Pecks.	Bush.	Qr.
8750 =	1.25 =	34.659 =	1					
17500 =	2.5 =	69.318 =	2 =	1				
70000 =	10 =	277.274 =	8 =	4 =	1			
140000 =	20 =	554.548 =	16 =	8 =	2 =	1		
560000 =	80 =	2218.191 =	64 =	32 =	8 =	4 =	1	
4480000 =	640 =	17745.526 =	512 =	256 =	64 =	32 =	8 =	1

Apothecaries' Measure.

The gallon of the former wine measure, and of the present Apothecaries' measure, contains 58317.765 grains weight of distilled water, or 231 cubic inches, the ratio to the imperial gallon being nearly as 5 to 6, or as 0.83311 to 1.

1 gallon	=	8 pints.
1 pint 0	=	16 ounces.
1 ounce f ℥	=	8 drachms.
1 drachm f ℥	=	60 drops or minims.

or,

Gallon.	Pints.	Ounces.	Drachms.	Minims.	Grains of Dist. Water.	Cub. Inch.
1	= 8	= 128	= 1024	= 61440	= 58317.765	= 231
	1	= 16	= 128	= 7680	= 7289.721	= 28.875
		1	= 8	= 480	= 455.607	= 1.805
			1	= 60	= 56.951	= 0.226

French Decimal Measure of Capacity, Litre = 61.0271 *British cubic inches, or* 15406.771 *grains of distilled water.*

		Cubic Inches.		Grains of Dist. Water
Millilitre	=	0.061	=	15.407
Centilitre	=	0.6103	=	154.068
Decilitre	=	6.10271	=	1540.677
Litre	=	61.0271	=	15406.771

Lineal Measure.

The imperial standard yard is divided into 36 inches, and it has been found that a pendulum vibrating seconds of mean time in a vacuum at the level of the sea, in the latitude of London, the thermometer being at 62°, and the barometer at 30 inches, measures 39.1393 inches.

12 in.	=	1 foot				
36	=	3 feet	=	1 yard		
198	=	16½	=	5½ yards	= 1 pole	
7920	=	660	=	220	= 40 poles	= 1 fur.
63360	=	5280	=	1760	= 320	= 8 furs. = 1 mile.

3 E

French Measure of Length—Metre = 39.37079 *imperial inches.*

Millimetre	=	0.03937079) imperial inches
Centimetre	=	0.3937079
Decimetre	=	3.937079
Metre	=	39.37079

The French toise = 6.39495 imperial feet

.... pied = 1.065825 .... foot

TABLE shewing the Weight in Grains of various Measures (Apothecaries') of different fluids.

	Specific Gravity.	Weight in Grains of			
		1 Pint.	1 Ounce.	1 Drachm.	1 Minim.
Distilled Water............	1.000	7289.72	455.61	56.95	.949
Sulphuric Ether...........	0.720	5248.60	328.04	41.00	.683
Alcohol......................	0.796	5802.61	362.66	45.33	.755
Solution of Ammonia.....	0.925	6742.99	421 43	52.68	.878
Muriatic Acid..............	1.118	8149.90	509.37	63.67	1.061
Nitric Acid..................	1.480	10788.78	674.30	84.28	1.404
Sulphuric Acid.......	1.848	13471.40	841.96	105.24	1.754

MODE OF REDUCING TO EACH OTHER'S STANDARD, DEGREES IN FAHRENHEIT'S, REAUMUR'S, AND THE CENTIGRADE THERMOMETERS.

2861. The space between the boiling and freezing points of water is divided into

180 parts or degrees in Fahrenheit's Thermometer.

100 .... in the Centigrade.

80 .... in Reaumur's.

Therefore

Fahren.		Cent.		Reaum.
180 degrees	=	100	=	80
1	=	$\frac{5}{9}$	=	$\frac{4}{9}$
$1\frac{4}{5}$........	=	1	=	$\frac{4}{5}$
$2\frac{1}{4}$........	=	$1\frac{1}{4}$	=	1

2862. In Fahrenheit's Thermometer the graduation begins at 32 degrees below the freezing point of water. The Centigrade and Reaumur's commence at this point.

Accordingly,

1. To reduce the Centigrade degrees to Fahrenheit's, multiply by 9, divide by 5, and add 32. Thus,

$$40 \text{ C.} \times 9 = 360 ; \frac{360}{5} = 72 ; 72 + 32 = 104 \text{ Fahrenheit.}$$

$$\text{Formula } \frac{\text{C.} \times 9}{5} + 32 = \text{F.}$$

2. To reduce Fahrenheit's to the Centigrade, subtract 32, multiply by 5, and divide by 9. Thus,

$$104 \text{ Fahr.} - 32 = 72 ; 72 \times 5 = 360 ; \frac{360}{9} = 40 \text{ Centigrade.}$$

$$\text{Formula } \frac{\text{F.} - 32 \times 5}{9} = \text{C.}$$

3. To reduce Reaumur's to Fahrenheit's, multiply by 9, divide by 4, and add 32. Thus,

$$\text{R. } 32 \times 9 = 288 ; \frac{288}{4} = 72 ; 72 + 32 = 104 \text{ Fahr.}$$

$$\text{Formula } \frac{\text{R.} \times 9}{4} + 32 = \text{F}$$

4. To reduce Fahrenheit's to Reaumur's, subtract 32, multiply by 4, and divide by 9. Thus,

$$\text{Fahr. } 104 - 32 = 72 ; 72 \times 4 = 288 ; \frac{288}{9} = 32 \text{ R.}$$

$$\text{Formula } \frac{\text{F.} - 32 \times 4}{9} = \text{R.}$$

5. To reduce Reaumur's to the Centigrade, multiply by 5, and divide by 4. Thus,

$$\text{R. } 32 \times 5 = 160 ; \frac{160}{4} = 40 \text{ Centigrade.}$$

$$\text{Formula } \frac{\text{R.} \times 5}{4} = \text{C.}$$

6. To reduce the Centigrade to Reaumur's multiply by 4, and divide by 5. Thus,

$$\text{C. } 40 \times 4 = 160 \,; \ \frac{160}{5} = 32 \text{ Reaum.}$$

Formula $\dfrac{\text{C.} \times 4}{5} = \text{R.}$

TABLE shewing the Correspondence between Fahrenheit's, Reaumur's, and the Centigrade Thermometers.

F.	C.	R.	F.	C.	R.	F.	C.	R.	F.	C.	R.	F.	C.	R.
-40	40	-32	+14	-10	- 8	+ 68	+20	+16	+122	+50	+40	+176	+ 80	+64
- 31	-35	-28	+23	- 5	- 4	+ 77	+25	+20	+131	+55	+44	+185	+ 85	+68
- 22	- 30	-24	+32	0	0	+ 86	+30	+24	+140	+60	+48	+194	+ 90	+72
-13	-25	-20	+41	+ 5	+ 4	+ 95	+35	+28	+149	+65	+52	+203	+ 95	+76
- 4	-20	-16	+50	+10	+ 8	+104	+40	+32	+158	+70	+56	+212	+100	+80
+ 5	-15	-12	+59	+15	+12	+113	+45	+36	+167	+75	+60		&c.	

In this table it will be observed that the numbers in Fahrenheit's scale advance by 9, in the Centigrade by 5, and in Reaumur's by 4. For an account of Daniell's pyrometer, the reader is referred to the Philosophical Transactions for 1830.

CHAP. III.—METHODS OF ESTIMATING THE SPECIFIC GRAVITIES OF SOLIDS, LIQUIDS, AND GASES.

2863. Water has been fixed upon as the standard of comparison in estimating specific gravities ; and its specific gravity has been called 1.

2864. In all experiments for ascertaining the specific gravities of different substances, particularly of gases, great attention must be paid to the temperature, as their volume varies with the degree of heat to which they are exposed.

To find the specific gravity of a solid body heavier than water,—First weigh

Fig. 480.
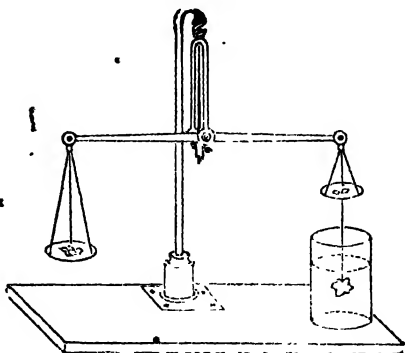
the solid in air ; then weigh it in water by a hydrostatic balance, in the manner represented in the accompanying figure (480), using a very fine thread, or a hair to suspend it from the bottom of one of the scales.   The difference in the results will express the weight of a quantity of water equal in bulk to the solid whose specific gravity is to be determined, and the following proportion will give its specific gravity in relation to water : As the weight of the water equal in bulk to that of the solid is to the weight of the solid itself, so is the specific gravity of water to the specific gravity of the solid.   Thus,

If the solid weigh 100 grains in air, and 60 grains in water, then 100—60, or 40 : 100 : : 1 : 2.5. The specific gravity of the solid is therefore 2.5 compared with that of water.

2865. If the solid should be lighter than water, a more complicated process will be necessary. Attach to the light solid, by a slender thread, another body of such a weight, that when tied together they shall sink in water, having previously weighed the heavier solid in water, and each in air ; then weigh them together in water, and from the difference between their weight in water and their weight in air, subtract the difference between the weight of the heavy solid in air and its weight in water ; the remainder will shew the weight of a quantity of water equal in bulk to the light body, and we can then find its specific gravity in the way directed above.   Thus,

If the weight in air of the light solid be 10 and of the heavy solid 20 ; and if the weight of the heavy solid in water be 18, and of the two together 7,—then

From their weight in air, . .	20 + 10 = 30
Subtract their weight in water,	7
	23
And from this subtract 20 — 18 = 2	2
The remainder	21

expresses the weight of a quantity of water equal in bulk to the light solid, and the following proportion will give us its specific gravity,

21 : 10 : : 1. : 0.47619,—the specific gravity of the lighter solid.

2866. Where a hydrostatic balance cannot be procured, the following method may be adopted : Weigh the solid and put it into a vessel full of water, the weight of which with the water is known : the solid will displace a quantity of water equal in

bulk to its own ; weigh the vessel again, having either taken out
the solid body, or put an equal weight in the opposite scale ;—
the difference between the present weight of the vessel and its
former weight will express the weight of a quantity of water
equal in bulk to the solid body, from which, by the same propor-
tion as in the former instances, we can estimate the specific gra-
vity of the solid body.   Thus, if the vessel when full of water
weighed 1000, and after some of the water had been displaced
by the solid body and the solid removed, or a counterpoise placed
in the opposite scale, it weighed 900 grains,—100 grains of water
were displaced by the solid body—and if the solid body in air
weighed 300 grains, then the following proportion will give its
specific gravity :

$$100 : 300 : : 1 : 3.$$

2867. If the solid body be soluble in water, some other fluid,
as oil, alcohol, ether, or a saturated solution of the substance
itself must be used, its specific gravity being previously ascer-
tained. We must first find the specific gravity of the solid, con-
sidering the fluid used as a standard of comparison, and making
the number representing its specific gravity the third term in
the proportion, in the same manner as when water is used ; and
then, by simple proportion, reduce the product to the standard
of water. Thus, if the specific gravity of the fluid used be 1.2,
and, considering it as a standard of comparison, the specific gra-
vity of the solid be 1.8, then the following proportion will give
us its real specific gravity :

$$1.2 : 1.8 : : 1. : 1.5.$$

2868. When the substance, the specific gravity of which is to
be ascertained, is in the form of a powder, the following method
will be found most convenient. Take a glass tube bf, three

feet in length, and open at both ends. The wide part
bc is to be about $\frac{4}{10}$ of an inch in diameter, and the
narrow part cf about $\frac{2}{10}$, communicating with each
other by a very small aperture at c, which allows air
to pass, but is sufficiently small to prevent any powder
from going through. The upper opening at b is to be
ground, so that it can be accurately closed by a glass
plate a. The substance whose specific gravity is to
be determined, is put into the wide part of the tube bc,
which is then to be placed in a wider tube containing
mercury g, making it descend till the fluid metal shall
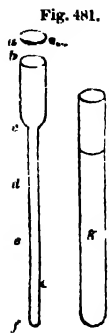
have reached the aperture at c. Then fix the cover, making it air-tight with a very small quantity of lard, and lift it perpendicularly out of the mercury till the aperture at c shall have been raised above the surface of the mercury in the tube to a height exactly equal to half the height of the barometer at the time the experiment is made, and mark the point at which the smaller tube is cut by the fluid, which we shall suppose in the present instance to be d. The air within that part of the tube in which the powder has been placed being now subjected to the pressure of only half an atmosphere, it expands to double its former volume, one-half still remaining within $b\,c$, while the rest occupies $c\,d$; the space it includes representing, therefore, the total bulk of air included at first along with the powder in $b\,c$ at the ordinary pressure. The powder is now withdrawn, and the process repeated with $b\,c$ full of air only, when it is obvious that the mercury will not stand so high within the tube $c\,f$ as before, and supposing it to rise only to e, then the space $c\,e$ will contain a quantity of expanded air, equal in bulk exactly to what would be contained in $b\,c$ before lifting up the tube. Since $c\,e$ then represents a space exactly equal to that within $b\,c$, and $c\,d$ a space equal to the volume of air in $b\,c$ when the powder was in it, then $d\,e$, the difference between them, shews the space occupied by the powder when it was in $b\,c$. In this manner, then, we are enabled to find out a space exactly equal in bulk to that of the solid matter in the powder, and if the stem be graduated so as to express in grains the quantity of water which it can contain, we have only to weigh the powder in air, and compare its weight with that of the equal bulk of water, to ascertain its specific gravity.

SPECIFIC GRAVITY OF LIQUIDS.

2869. Take a bottle of a known weight, fill it with distilled water, and weigh it carefully; then pour out the water, and after drying the bottle, fill it with the liquid to be tried. The following proportion will give its specific gravity : As the weight of the distilled water is to the weight of the liquid, so is 1 to the specific gravity required. Thus, if the weight of the distilled

water be 300 grains, and that of the liquid 600, the following is the proportion we must use :—

$$300 : 600 :: 1. : 2.$$

2870. The areometer, or hydrometer, Fig. 482, is a convenient instrument for ascertaining the specific gravities of liquids. It consists of a long, straight, graduated stem, on which numbers are marked at the points to which the instrument sinks in liquids of the specific gravities marked at these points. Thus, in distilled water it will sink to 1, and in nitric acid to 1.48. It is made of different materials, according to the nature of the liquids whose specific gravities are to be ascertained with it.

Fig. 482.
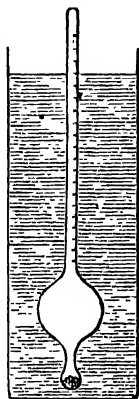
2871. Lovi's beads are also very useful for ascertaining the specific gravities of liquids. These are small balls made of glass, with numbers marked on them indicating the specific gravity of those liquids in which they float without any tendency either to sink or rise to the top. Those that float on the surface shew that the liquid has a greater specific gravity than the number marked on them expresses, while those that sink indicate the reverse, being heavier than an equal bulk of the fluid.

SPECIFIC GRAVITY OF GASES.

2872. Atmospheric air is taken as a standard of comparison in estimating the specific gravity of gases, and represented by the number 1. Their specific gravities are found out in the same manner as those of other substances, viz. by comparing the weight of equal bulks of them and of the substance which is taken as a standard of comparison.

2873. For this purpose, a flask provided with a stop-cock is accurately weighed and attached to an air-pump or exhausting syringe, which is worked in the usual manner ; and, when the gas whose specific gravity is to be tried has no action on atmospheric air, it is not necessary to exhaust it to a very great degree. The stop-cock fixed to the flask is then turned, when it is weighed again to ascertain the quantity of air extracted. It is then screwed on to a jar (placed over a pneumatic trough)

containing the gas whose specific gravity is to be determined, and on opening the stop-cock, a quantity of gas is forced by the pressure of the atmosphere into the flask, exactly equal in bulk to the air which had been withdrawn, if the jar be depressed in the liquid till it shall be level both within and without. If the flask be then detached from the jar, it is obvious that, by weighing it again, we can find out the weight of a measure of gas exactly equal in bulk to that of the air whose weight was found out by the first operation. See page 75, Fig. 85.

2874. For example, if the flask should weigh 570 grains when full of air, and 560 after the exhaustion, then the quantity of air which has been withdrawn weighs 10 grains.

	Grains
Weight of flask with air, .	570
Weight of flask after exhaustion,	560
Weight of air withdrawn,	10

And if it shall weigh 580 grains after admitting the equal volume of the gas whose specific gravity is to be determined, then it must be twice as heavy, or its specific gravity must be twice as great as that of atmospheric air.

	Grains
Weight of flask with gas, .	580
Weight of flask after exhaustion,	560
Weight of gas introduced,	20

2875. When the gas whose specific gravity is to be ascertained acts chemically on atmospheric air, the latter must be withdrawn as completely as possible by repeated exhaustions, filling it after each with some gas which is not affected by the other, and then proceeding in the usual manner.

2876. In operating with gases, it is also necessary to attend to the pressure of the atmosphere as indicated by the barometer, and the quantity of watery vapour which they may contain. The formulæ given for making corrections when the barometer is not at the point adopted as a standard of comparison, and for the quantity of watery vapour which the gases tried may contain, must be carefully attended to. See the Tables.

2877. It may be also necessary to remark, that when the specific gravity of a gas is ascertained in the manner that has been described, no variation in the pressure of the atmosphere of any

consequence can take place in the short space of time necessary
for this purpose, and equal bulks of air and the gas whose spe-
cific gravity is to be found out having been weighed precisely
under the same circumstances with respect to pressure, no cor-
rections on this account are required.

CHAP. IV.—LUTES AND CEMENTS.

2878. A great variety of lutes and cements are required for
different chemical operations, and as most of those that are pe-
culiar to particular processes have been already described along
with the method of applying them, it will be sufficient in this
place to state those that are more generally useful. They are
employed principally with the view of rendering joinings tight
so as to confine liquids or gases, or to give support to, and pro-
tect from the action of the fire, vessels that are apt to be de-
stroyed by exposure to a high temperature.

2879. In a great number of operations, joints may be made
sufficiently air-tight by a paste made of linseed meal, pease meal,
flour, or starch (using hot water with the latter), covering them
occasionally, where it may be necessary, with a small piece of
linen cloth dipped in prepared glue, which may be rendered
still more secure by tying a stout thread round them. Small
slips of bladder or gum paper will often be found sufficient for
all that is required. Powdered gum is frequently used, and a
strong solution of it in water should always be kept, which may
be thickened with finely pounded chalk to form the mixture
termed chalk lute, and which does extremely well for connect-
ing all kinds of glass or earthen tubes that are not to be ex-
posed to a high temperature, or to the action of corrosive liquids
or vapours.

2880. Another class of lutes which are used for rendering the
joinings of apparatus for experiments with the gases air-tight,
are composed principally of wax with various quantities of olive
oil, resin, oil of turpentine, or other substances of a similar na-
ture. The gas-lute referred to in this work is composed of one

part of wax and three of lard, heating them together till a fluid of a uniform consistence is obtained.

2881. By increasing or diminishing the proportion of wax it may be easily rendered of various degrees of consistence, so as to make it fit for a number of different purposes.

2882. For fixing glass-tubes into retorts or bottles not to be exposed to the action of corrosive liquids, common sealing wax may be employed, tying the glass-tube round with thread till it fits the aperture in which it is to be fixed. A better cement for this purpose, however, is obtained by melting bees-wax with an eighth part of common turpentine; it may be made into sticks like sealing wax, melting it and spreading it with a hot iron when required for use. It is less brittle than common sealing wax, and by using a larger portion of turpentine, a soft cement may be obtained, very useful for closing bottles accurately that contain substances which must not be exposed to the action of the air.

2883. Four parts of resin melted with one of bees-wax and mixed with one part of brick-dust, give a cement that is much employed in joining pieces of apparatus that are to be permanently fixed together.

2884. Varnishes may often be employed with advantage for rendering a number of joinings tight, as in fastening a bladder or oiled silk-bag to a stop-cock, dipping a piece of stout linen cloth in them, and tying it with thread after rolling it round. Thick copal varnish, made by dissolving copal in oil of turpentine, will be found better adapted for this purpose than most other kinds of varnishes; it should be purchased from the painters, as the student will find considerable difficulty in preparing it.

2885. To confine acrid vapours, glaziers' putty may be employed; it is made by beating up chalk with drying linseed oil, and is similar in its qualities to the fat lute, as it is termed, which is made by treating clay in the same manner after drying it thoroughly and reducing it to a fine powder.

2886. A great number of useful lutes and cements are made by mixing lime with mucilaginous, albuminous, and gelatinous liquids. Slaked lime in fine powder made into a paste with the white of an egg after beating it in a cup, or with a strong so-

lution of glue, sets very quickly, and may be applied most conveniently by spreading it on slips of cloth.

2887. Plaster of Paris is used in the manner described in the note at page 259 ; and by mixing it up with a mucilaginous liquid or a solution of gelatine, instead of water, it may be kept for a longer time before it begins to set.

2888. For coating glass-vessels so as to enable them to bear a red heat, a mixture of dry sand, powdered clay, and cut thread, is to be made into a stiff tenacious paste with water, using no more clay than is necessary to make the sand adhere, and mixing the cut thread with the other materials before adding any water ; the paste is then to be put equally round the retort and allowed to dry slowly for two or three days, heating it eventually at an open fire before it is used.   Thin iron-wire wrapped round the coating serves to bind it together when it becomes hot, the whole being rubbed over afterwards with a portion of the mixture of sand and clay.

2889. If an iron or earthen vessel is to be coated before exposing it to a high temperature, the directions already given for coating the iron-retort used for the preparation of potassium, shew the best method of proceeding in cases of this kind.   Most earthen vessels become very porous, however, at a high temperature, and in particular processes a great portion of the products that would otherwise be obtained are lost.   To obviate this, Mr Willis succeeded in preparing a lute which is well known by his name ; the following is the method of applying it.   An ounce of borax is to be dissolved in half a pint of water, and slaked lime is to be added to the solution till a thin paste is obtained.   This is to be spread over the retort with a brush, and covered when dry with a lute made of linseed oil and slaked lime.   It may then be put aside for a day or two to dry slowly, when it will be fit for use.   The first coating fuses at a high temperature, and forms a glazing over the earthen retort that prevents vapours from passing through it during distillation, and the second protects it from the fuel, and renders it less liable to be broken as it cools.

CHAP. V.—THE BLOWPIPE.

2900. The blowpipe is an instrument of great value to the practical chemist, assisting him in his analytical investigations, and often enabling him to obtain in a few minutes, and without the assistance of any more complicated apparatus, all the information he may desire. The student who knows how to use it, may, at little expense, either of time or materials, perform a very wide and interesting range of experiments, which will impress upon his mind the most important chemical relations of the materials with which he operates.

2901. The value of the blowpipe depends more especially upon the circumstance that, with it, almost all furnace operations can be imitated on the small scale ; the flame being applied so as to produce either an oxidating or deoxidating effect, and the materials subjected to its influence being at the same time mingled with any reagents that may be required to develope their nature. The intensity of the heat communicated depends upon the elevated temperature of flame, and the rapid succession of heated particles that are made to impinge on the essay or subject of experiment.

2902. For all ordinary purposes, a common brass blowpipe will be found quite sufficient, if it be well made, and the aperture at the extremity, which need not exceed the fortieth of an

Figs. 483   484.   486   487.   inch in diameter, be round and smooth ; it should be tipped with ivory where it is held in the mouth. Fig. 483 shews the common form of this blowpipe. Fig. 484 represents Dr Black's blowpipe, the hollow conical vessel serving not only to condense the moisture of the breath, which is often found troublesome in working with the common blowpipe, but also to regulate the pressure. Fig. 486 shews Dr Wollaston's

blowpipe, the extremity of which has a platinum nozzle, and
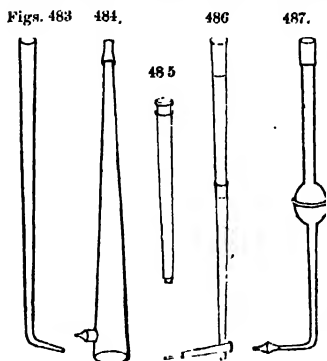
which can be taken to pieces that are made so as to fit into one another, and occupy less room than a pencil case, as in Fig. 485. Again Fig. 487 represents a form of blowpipe in which the ball condenses the moisture of the breath, and serves also to hold several nozzles of different sizes, which may be fitted to the extremity, according to the nature of the operation for which they may be required.

2904. Glass blowpipes are also very frequently used, the aperture at the extremity is not so apt to be choked up as in metallic blowpipes, and, were they not so liable to be broken, they would always be preferred.

2905. For all ordinary purposes, **Dr Black's** blowpipe is the best, if a proper nozzle be attached, made in the manner represented in the annexed figure. It is a section of the one I

Fig. 489.

Fig. 488.
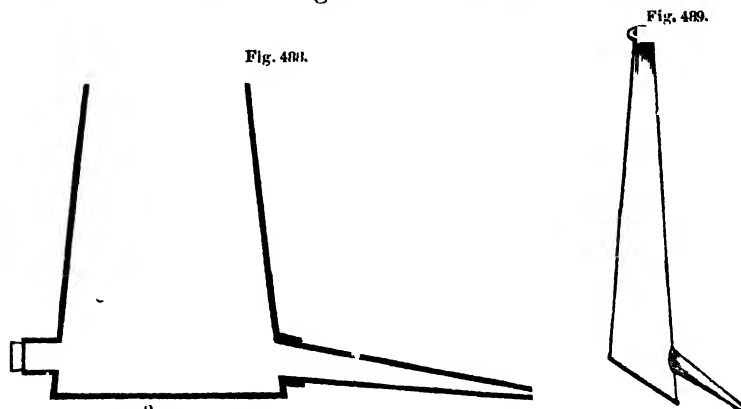
generally employ, shewing precisely the size and form of the base to which the nozzle is fixed, and is made of japanned tinned iron, the nozzle being placed in the position shewn ; so that when it is held in the mouth alone, as in Fig. 490, the face may be held so far back from the flame employed, as to be out of the current of offensive warm air ascending from it. If the nozzle be long and narrow, much force is required to keep up the blast, but when it is wide where it joins the base of the blowpipe, and tapers to a small opening, much less force is required in operating with it. The aperture near the lower part opposite the nozzle, is often omitted, though occasionally it is useful in removing condensed moisture. Fig. 489 shews another variety of this blowpipe, in which the nozzle is placed at

a more acute angle, to enable the head to be held more completely away from the flame when it is used for tube-apparatus, when both hands must be at liberty.

2906. The nozzle is usually made of brass or copper, and occasionally of platinum. None gives so fine a flame as a glass nozzle, but from its brittleness it is not generally used. The extremity of the nozzle cannot be too carefully attended to. The slightest irregularity or obstruction in the aperture alters the character of the flame ; it should be cleared out when obstructed, with the greatest caution, and so as to prevent it assuming a trumpet form, however slight. Beginners are frequently apt to destroy their blowpipes by pressing the extremity upon the subject of experiment, a practice which soon renders the nozzle of the blowpipe useless.

2907. The first thing that the student ought to do with the blowpipe, should be to learn to keep up a continued blast at a candle with his mouth, while he breathes freely through his nostrils. For this purpose, he must, in the first place, distend his cheeks like a trumpeter, and breathe solely through his nostrils, never allowing his cheeks to collapse. When he can do this easily, he should put a blowpipe with a very small aperture into his mouth, placing the pointed extremity in the flame of a candle; during expiration, a small part of the expired air will continue to pass through the tube, and during inspiration also, air will continue to pass through the tube, if he shall have made his cheeks sufficiently tense and elastic by distending them previously with air, and the same process goes on at each successive expiration and inspiration. Such is the mechanical rule for learning the method of keeping up a continued blast of air with this instrument, which I have seldom seen fail in enabling the beginner to acquire this art in five or ten minutes, and, as considerable practice is necessary before he can be able to use it freely, he cannot commence too early with it. At first, he should take it up frequently at intervals of an hour or two, and not continue working with it for more than a quarter of an hour ; he will soon, however, learn to keep up a continued blast without any difficulty, or distending his cheeks so much as to make it feel tiresome. It is necessary, however, to do so when he begins, as he will not otherwise be able to acquire speedily the method of blowing a constant flame.

2908. During inspiration, the blast is kept up solely by the

air from the reservoir within the cheeks, from which it is pressed out by the contraction of the muscles, and the stock renewed at each successive expiration.

2909. The flame of an oil or spirit lamp, or of a large candle, does very well for blowpipe experiments ; but nothing will be found so convenient as a gas-lamp, which is not only easily managed, and requires none of the trouble necessary for adjusting the others, but allows the flame to be increased or diminished to any convenient size, by merely turning the stopcock. The
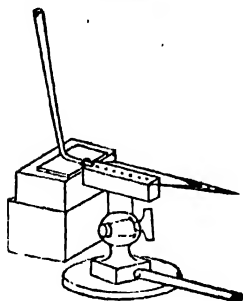
Fig. 490.

figure represents a gas-lamp constructed for blowpipe experiments, which I have now used for several years. It is connected by a flexible tube, fitted to the lower part, with the main-pipe, supplying the rooms with gas ; and when it is on full cock, it gives a flame about three inches high, and an inch and a half long, the gas escaping through a double row of small apertures, placed along the top. With a little practice, the whole of this flame may be easily thrown into one blast with a common blowpipe having a larger nozzle than usual, and the heat produced is so great, that a piece of silver of the size of a shilling may be melted in it in a few seconds, though held in the open air by a pair of pincers, and not supported by any charcoal to increase the power of the flame. It is seldom that so large a flame is required ; the blowpipe is shewn in the figure in the manner it should be arranged, when the use of both hands is required in making and adjusting tube apparatus ; the extremity is put through a small ring, made by fixing a bent iron-wire in a piece of lead, which is supported to a proper height by blocks of wood placed below. When the height of the flame has been properly adjusted, the position of the extremity of the blowpipe may be easily regulated by the mouth, while blowing through it, so that both hands are left free for managing the tube apparatus. The same contrivance may be adopted also in operating with an oil or spirit lamp.

2910. Any ordinary burner may be converted into a blowpipe burner by covering it with wire-gauze, so as to diminish the impetus with which it escapes. See Fig. 151, page 163.

2911. But in the greater number of cases, a gas-lamp will not be accessible to the beginner, and then a lamp charged with oil or tallow may be employed.   It may be made of tinned iron,
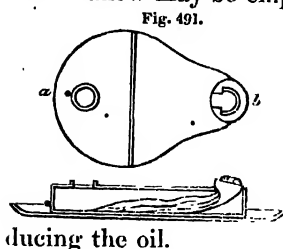
Fig. 491.

brass, or copper, and should be so arranged that the flame may be directed horizontally, or downwards, or upwards, at any angle required.   This is effected by placing the opening for the wick at one extremity, as at *b* in Fig. 491 ; *a* is the aperture for introducing the oil.

2912. When it is necessary to heat an extensive surface, a blowpipe with a wider aperture should be used, and held at a little distance from the flame, or, the blast must be made to strike upon the wick, when a lamp or candle is employed.   On the other hand, when it is necessary to concentrate the heat upon a single point, the extremity of the blowpipe should be introduced a little way within the flame, so as to give a well-defined and luminous cone, surrounded by a thinner flame, which projects beyond it ; the interior portion has a blue colour, while the exterior is much lighter, and possesses very different properties, the point of greatest heat being at the extremity of the blue cone.

2913. Fig. 492 represents the general appearance of the rough
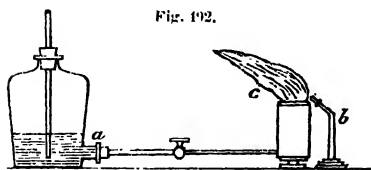
Fig. 492.

flame produced by placing the nozzle at a little distance from the flame ; *a* is the reservoir of oil ; *b* the nozzle supplied with air from any convenient apparatus, or from the mouth by a flexible tube, and *c* the luminous rough flame. The peculiar form of lamp is not necessary ; it is introduced to shew one of the numerous varieties of lamps which have been much used in blowpipe experiments.

2914. The inner flame is usually termed the *deoxidating flame* ; it contains less air than is necessary for the combustion of the inflammable matter, of which it is principally composed, and any substance that is placed within it is subjected, not only

3 F

to a high temperature, but also to the action of the excess of in-
flammable matter, which has a great affinity for oxygen.   Any
substance placed in the exterior flame, again, which contains
more air than is necessary for the combustion of the inflam-
mable matter, is exposed to the action of the excess of oxygen
at a high temperature, and it is accordingly usually termed the
*oxidating flame.*

2915. A more minute examination of the flame will illustrate
peculiarities that demand careful attention.   These may be
studied by heating a small platinum wire in the flame, dipping it
into pounded borax, mixed with a minute quantity of peroxide
of copper, and heating it in the flame, as in Fig. 493; a blue
glass being formed in the oxidating flame, while a brown glass
or metallic copper is seen in the inner flame.
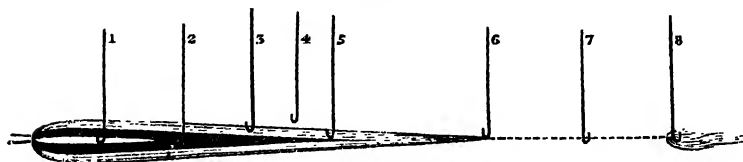
1, Indicates the inner oxygenating cone, very small, and pro-
duced by the air from the blowpipe.

2, The blue cone, which becomes entirely deoxidating when a
highly yellow and luminous flame is largely mixed with it.

3, Shews the outer flame, composed principally of products of
combustion·

4, The hot air beyond the outer flame, highly oxidating.

5, The point of greatest heat.

6, The termination of the visible flame.

7, The hot products of combustion, occasionally exerting an
oxidating or deoxidating influence, according to the nature of
the subject of experiment and the materials with which it is
mingled.

8, A point considerably beyond the visible flame, which al-
ways exerts an oxidating effect.

2916. When the platinum wire alone is held in the flame, no
peculiar appearance is presented; but with many substances, a
peculiar tint is observed, and this should be examined with the
wire held in all the different parts of the flame represented in

the preceding figure. No. 8 shews the appearance, when any compound containing sodium has touched the wire, as common salt, borax, and sulphate or carbonate of soda.

2917. The effect produced by the flame of the blowpipe, depends very much not only upon the management of the flame, but also upon the nature of the support on which the substances that may be examined with this instrument are placed. A charcoal support not only increases the heat, but assists materially in deoxidating a number of compounds. Supports made of earthenware, again, favour the action of the oxidating flame.

2918. The succeeding figures 494—510 inclusive, represent the instruments, &c. which are more commonly used in blowpipe experiments.

2919. Figs. 494 and 495 represent the form of wires of iron and platinum, which are continually used in blowpipe experiments. They may be made of all sizes, but should not be smaller than they are seen in the figures.

Figs 494. 495
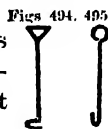
2920. Figs. 496 and 497 represent two platinum wires of the exact size and form which it will generally be found most convenient to employ; they are much better than iron wires, which are not used for ordinary purposes, except for occasional experiments when the others are not accessible.

Fig 496. 497.   498.
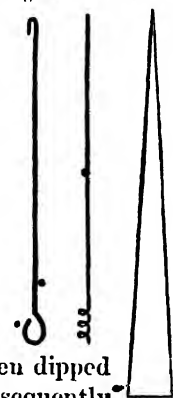
2921. Fig. 498 shews the size of small slips of glass or porcelain, which are often substituted for the metallic wires, especially where experiments with fluxes have to be performed.

In using wires and slips of glass or porcelain, they are generally heated first in the flame, then dipped into any of the fluxes, heated again, and subsequently brought into contact with a small portion of the subject of experiment, when they may be returned to the flame.

2922. Fig. 499 shews the platinum spoon. It is not so convenient for ordinary experiments as the wire. Two small platinum cups, Figs. 500, 501, of the size and form shewn, are still more convenient, and, like the wires, may be freely boiled in water or in muriatic acid, when this may be required, after using them at the blowpipe.

Fig. 499

Figs 500   501
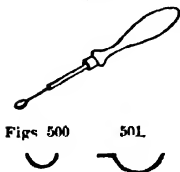
2923. Figs. 502 and 503 represent a small cup made of pipe-clay, of the exact size employed, supported on the extremity of a slip of glass. Cups of this kind are very useful as the effect of oxidation is well observed, and also the colour of any matter that melts or flows upon its surface.
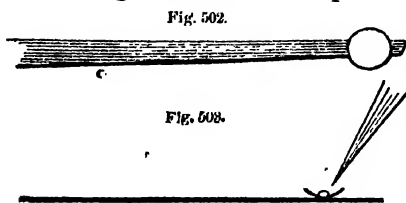
Fig. 502.

Fig. 503.

2924. Fig. 504 represents a thin slip of brass of the exact

Fig 504.

size used in making the cups, and about 1–16th to 1–20th of an inch in thickness. They are prepared by placing the brass upon a piece of paper, pressing pipe-clay softened by water upon it so as to fill up the apertures, after which it is laid upon the palm of the left hand and the clay pressed by one of the fingers of the right hand, so as to give them a cupped appearance. On allowing them to dry, they separate from the brass, after which they are gently heated, and ultimately exposed to a white heat before they become fit for use.

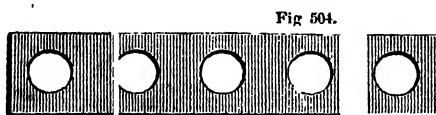2925. Fig. 505 represents a small cupel made of bone ashes, for removing lead from silver by the outer flame of the blowpipe, in the same manner as it is separated by the process of cupellation. See Silver.

Fig 505

2926. In all experiments where a deoxidating power is required, a charcoal support is commonly used—well burned charcoal producing no flame is preferred. Soft charcoal

Fig. 506.

gives the greatest heat; hard charcoal is more durable. A shallow cavity is usually made in the charcoal where the subject of the experiment is to be placed, but where great heat with a deoxidating power is required it may be sunk deep, as in figure 506.
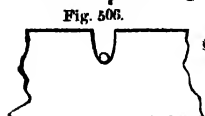
2927. When very small portions of matter are used, Mr Smithson recommends them to be supported on little pieces of clay, preparing these by striking a piece of clay between two pieces of paper till it forms a thin plate cutting it afterwards

with a pair of scissors, and heating it. The little masses exa-
mined are attached to these pieces of clay by touching them at
the extremity with a little clay made up with water. They
may be supported in the flame by placing them on charcoal, by
a pair of forceps, or on the point of a platinum-wire. Figs. 507. 508
Pumice-stone is frequently employed for the same pur-
pose, but it is too porous for a number of operations.

2928. Pincers or forceps of various sizes are much
used in experiments with the blowpipe. Those re-
quired merely for lifting small fragments of different
substances, may be made of the form seen in Figs. 507
and 508.

2929. Figs. 509 and 510 represent platinum tipped
forceps which are very useful in blowpipe experi- Fig. 509, 510.
ments ; *a a* are the brass handles, *d d* the platinum
tipped extremities, *c c* small pins by which the
platinum extremities are separated from each other
when pressed upon by the thumb and forefinger,
b b the connection of the blades. With these
forceps, any material to be experimented upon may
be held in the flame of the blowpipe. The figures
in this case represent the exact size of the forceps.

2930. Though the mouth-blowpipe is sufficient
for all ordinary purposes, many contrivances have
been made for increasing its power, and avoiding
the necessity of supplying the stream of air for the
blast by the lungs, one or two of which may now
be mentioned, along with some useful modifications
in the method of applying the heat.

2931. In the water-pressure blowpipe, the me-
thod of constructing which will be understood
from the annexed figure, a cylindrical iron-vessel
is placed within a cistern of water, two tubes being
fitted to the upper part, and a wide opening made below, so that
there may be a free communication between the water within
the cylinder, and the rest of the water in the cistern. When
the bellows are worked, air is forced into the cylinder through
the tube connected with them, a valve preventing its return.
while the water forced out of the cylinder rises in the cistern.
On opening the stopcock connected with the tube at the top of
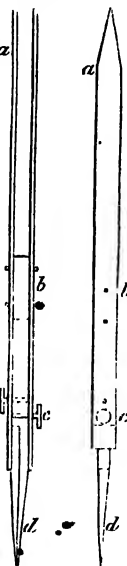
the cylinder, the water returns to its original level as the air

Fig. 511.

escapes, and if the air be made to pass through a blowpipe aperture of the usual size, a cylinder capable of containing a cubic foot of air, will give a continued stream of air for upwards of ten minutes, which may be renewed from time to time, as it is required. A large lamp should be used with this blowpipe, the wick being made about an inch thick, and separated at the top to the depth of a quarter of an inch to extend the flame ; the point of the nozzle, which is usually made of glass, is introduced a little way within it. The glass nozzle is fitted to the bent brass tube (continuous with the upper part of the stopcock), merely by tying it round with thread, and pressing it gently in, when it has been made to fit to it. The stopcock is fixed in a ball and socket joint, so that it may be moved easily in any direction.
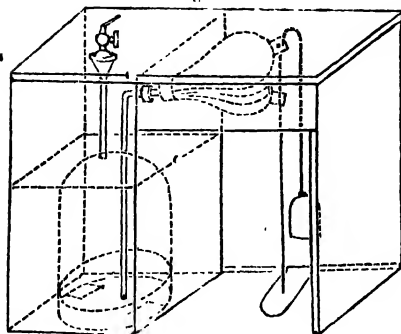
2932. A gasholder (Fig. 15, page 9) may be often used with advantage to supply a continuous stream of air for some time, connecting the aperture from which the air is expelled in the usual manner with a flexible tube which terminates in a nozzle

Fig. 512
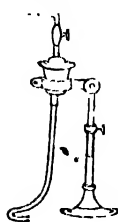
with a small aperture. Should this apparatus be preferred, a nozzle, such as is represented in Fig. 512 above the blowpipe table, may be fitted to any temporary stand, in the manner shewn in the annexed figure, so as to allow it to be easily elevated or depressed, as may be required. When the gasholder is filled with water, on emptying it, the supply of air may be kept up as before on returning the water.

2933. The annexed figure represents a more simple apparatus than any of the preceding; it is a modification of Danger's Blowpipe, who received a prize for its invention. It consists of a brass tube, terminating in a cup containing a brass ball, which acts as a valve : a tube is connected with the upper part of the cup, which divides into two branches, the one termi-

nating in an air-proof bag, and the other in a small aperture, or what is better, in a wide aperture, into which glass nozzles of various sizes may be introduced. The brass tube may be made about 12 inches long, and ⅜ths of an inch in diameter ; the cup an inch deep and an inch wide at the top ; ·the brass ball should be half an inch·in diameter. The brass clamp by which it is fixed to the table should be cast; so as to form the branches of the tube which lead to the bag and to the nozzle. The brass tube·should have a proper mouth-piece. On blowing into the tube, the ball is raised, ·and the air passes into the bladder. part of it escaping through the nozzle. The ball returns to its place the moment the blowing is discontinued, and on giving the necessary compression, a constant stream of air is propelled through the nozzle. The neces-
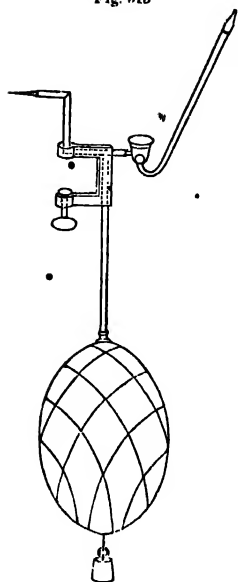
Fig. 513

sary compression is given most conveniently by putting a loose network round the bag, to which weights are attached, supporting them during the inflation. The bag may be made of Mackintosh's water-proof cloth. or a bladder may be employed.

2934. In the oxyhydrogen blowpipe, a mixture of oxygen and hydrogen gases is inflamed as it issues from a brass nozzle connected with two flexible tubes, one supplying oxygen, and another hydrogen, from separate gasometers. The hydrogen should be put on first and inflamed, and the oxygen should be allowed to mix gradually with it, increasing the quantity slowly, till the large flame of the hydrogen is reduced to a small pale blue pencil. Iron-wire is melted instantly when held in this flame, and by directing it upon a small piece of any solid substance, we can expose it to a higher temperature than in any other way, except by subjecting it to the action of a powerful galvanic battery.

2935. The gases have sometimes been mixed in the same gasometer, and many contrivances have been made to prevent the flame returning through the nozzle, which would cause a violent and dangerous explosion ; but though several of them are ex-

tremely ingenious, and must obviate every chance of explosion in the hands of an operator who has had some experience, it will be proper for the beginner to use a separate gasometer for each of the gases, allowing them to mingle only in the nozzle into which the flexible tubes are fixed.

2936. In most cases, the operator will have sufficient command over this blowpipe by merely holding the nozzle in his hand ; a support will often be found useful, however. It consists of a brass stand, with a moveable brass rod made to slide up and down in it, and which can be adjusted to any height by a screw fixed to the side. On the top of this rod there is a moveable joint supporting a sheath for the brass nozzle, so that by moving the sheath, or turning round the brass rod in the stand, the nozzle may be made to point in any direction, and kept steadily in any position in which it may be required.

Fig. 514.

2937. For a full detail, with respect to the method of using the mouth-blowpipe, I must refer to the treatises which have been written on this subject, mentioning some experiments which will enable the beginner to commence experimenting with it, and subjoining a table of the effects of the blowpipe flame on inorganic substances, taken from Mr Children's translation of Berzelius's Treatise on the use of the Blowpipe. The size of the substance submitted to the flame of the blowpipe need not be larger than a pea, and in most cases it will be found advantageous to take a much smaller portion ; this, however, must be regulated in a great measure by the nature of the substance to be operated on, the size of the flame which can be commanded, and the dexterity of the experimenter.

2938. Take a small piece of lead, not exceeding half a grain, and expose it to the oxidating flame on a clay cup, as in Figs. 503 and 504 ; when it is melted, a beautiful iridescent appearance will be seen on its surface, the lead speedily attracting oxygen, and being converted into the yellow oxide of lead, which is melted at the same time, and forms a glazing over the earthenware.

2939. Expose another piece of lead to the deoxidating flame, and if it be completely surrounded with this part of the flame, no oxide will be formed.

2940. Put some red oxide of lead on a piece of tile, and ex-

pose it to heat in the outer flame; it will part with a portion of its oxygen at this high temperature, and be converted into the yellow oxide of lead, though surrounded with an excess of oxygen, but it will not part with any more oxygen, though the heat may be sufficient to melt what remains.

2941. Put another portion of this oxide on a piece of charcoal to assist its reduction by the deoxidating flame; globules of metallic lead will be immediately obtained.

2942. Expose some metallic antimony to heat on charcoal in the usual manner; it will soon melt, revolve rapidly round its centre, and burn with a pale blue flame, producing a large quantity of white fumes. Zinc treated in the same manner burns with its characteristic rich-coloured flame.

2943. Expose some borax to heat on a tile till the water of crystallization is expelled, and a bead of glass is obtained.

Repeat this several times, mixing the borax successively with portions of the peroxide of copper, peroxide of manganese, oxide of chrome, chloride of gold, and a number of other substances. The glass that is formed in this manner will be rendered bluish-green by the peroxide of copper, purple by the peroxide of manganese, green by the oxide of chrome, and of a beautiful pink colour by the chloride of gold. A large piece of borax receives a very deep tint when it is merely touched with a glass rod dipped in a very dilute solution of the chloride of gold.

2944. Expose some metallic tin to the flame of the blowpipe; it will soon be melted and acquire a crust of oxide on its surface; then endeavour to reduce the oxide on charcoal. This will not be easily effected, unless the operator has acquired considerable command over the blowpipe, but if a little carbonate of soda or potassa be put over the oxide of tin, globules of metallic tin may be obtained with great facility.

2945. Expose a small piece of the bipersulphate of copper (weighing about 1 or 2 grains) to the deoxidating flame of the blowpipe, after placing it upon charcoal; and continue the heat till it is completely decomposed, and a round globule of metallic copper is procured.

2946. These experiments will be sufficient to guide the student in studying the subjoined table, from which he should select and perform all those that may appear most interesting.

2947. The great value of BORAX as a flux, depends princi-

pally upon its tendency, after its water of crystallization has been expelled, to form very fusible compounds with a number of substances, from the appearance of which their nature may in general be inferred.   CARBONATE of soda is used for the same purpose, and also to promote the reduction of metallic oxides (2944).   Phosphate of soda and ammonia (salt of phosphorus) is prepared by mixing equal parts of phosphate of soda and phosphate of ammonia in solution, crystallizing afterwards by evaporation.   On exposure to heat at the blowpipe, the ammonia is disengaged, and the excess of acid now in combination with the soda combines with salifiable bases, and renders them more easily fusible.   NITRE imparts oxygen readily ; TIN, again, is used as a deoxidating agent ; IRON precipitates many metals, as copper, lead, and antimony ; and NITRATE OF COBALT serves to distinguish alumina from magnesia, producing a blue colour with the one, and a faint rose-red with the other.

SYNOPTIC TABLE

THE PRINCIPAL CHARACTERS OF THE EARTHS AND METALLIC OXIDES BEFORE THE BLOWPIPE.

[EXTRACTED FROM BERZELIUS'S TREATISE ON THE BLOWPIPE, AS TRANSLATED BY MR CHILDREN.]

ABBREVIATIONS.—O. F. *Oxidating Flame.*—R. F. *Reducing or Deoxidating Flame.* — = parts; *Equal parts of the Assay and Flux.*—N. C. *Nitrate of Cobalt.*— Fl. *Flaming.*—C. *under the column of either of the Fluxes, means that the support is Charcoal.*—P. F. *Platinum Foil.*— P. W. *Platinum Wire.*—A Brace { *, refers to the first column only, and includes all those which are contained in the space which it comprehends.*

| ASSAY. | HEATED ALONE ON | |
	PLATINA.	CHARCOAL.
1. Alkalies.		
2. Baryta.	2. Infusible.	2. Infusible.
a. *Hydrate.*	a. Bubbles up and fuses.	a. Is absorbed.
b. *Carbonate.*	b. Fuses readily into a clear glass enamel, white on cooling.	b, Becomes caustic and is absorbed.
3. Strontia.	3. Infusible.	3. Infusible.
a. *Hydrate.*	a. Like baryta.	
b. *Carbonate.*	b. Fuses with moderate heat at the surface; —great brilliancy; tinges strong R. F. red; becomes alkaline.	
4. Lime.	4. No change.	
a. *Carbonate.*	a. Becomes caustic and alkaline; emits brilliant white light.	
5. Magnesia.	5. No change.	5. No change.
6. Alumina.	6. No change.	6. No change.
7. Glucina.	7. No change.	7. No change.
8. Yttria.	8. Like Glucina.	8. Like Glucina.
9. Zirconia.	9. Infusible; emits intense light.	9. Infusible, emits intense light.
10. Silica.	10. No change.	10. No change.
11. Molybdic Acid.	11. Fumes and fuses; brown-yellow on cooling; in R. F. blue; intense heat, brown.	11. Fuses, and is absorbed, and partly reduced.

ASSAY.	HEATED ALONE ON	
	PLATINUM.	CHARCOAL.
12, Tungstic acid.	12. R. F. blackens, but not reduced.	12. The same.
13. Oxide of Chrome.	13. No change.	13. The same.
14. Antimony.		14. Fuses readily ; white fumes, which copdense into pearly crystals.
a. Oxide of Antimony.	*a.* Fuses readily, and sublimes in white fumes ; *precipitated oxide* burns like tinder into antimonious acid.	*a.* Fuses readily, and reduces ; colours the flame greenish.
b. Antimonious Acid.		*b.* Does not fuse, nor reduce ; gives a bright light.
c. Antimonic Acid.		*c.* Whitens ; is changed to antimonious acid.
15. Oxide of Tellurium.	15. F. fuses and fumes.	15. Fuses, effervesces, and reduces,
16. Oxide of Columbium.	16. No change.	16. The same.
17. Oxide of Titanium.	17. No change.	17. The same.
18. Oxides of Uranium.		18. Peroxide becomes protoxide ; blackens, but does not fuse.
19. Oxides of Cerium.	19. Protoxide becomes Peroxide	19. Peroxide does not alter.
20. Oxide of Manganese.		20. Not fused ; becomes brown in a strong heat.
21. Oxide of Zinc	21. Yellow while hot ; white when cold ; does not fuse, but gives out great light when very hot, and white fumes, which condense like wool.	
22. Oxide of Cadmium.	22. F. no change.	22. Soon dissipates, leaves a red or orange yellow powder on the charcoal.
23. Oxide of Iron.	23. O. F. no change.	23. R. F. blackens, and becomes magnetic.
24. Oxide of Cobalt.	24. No change.	24. The same.
25. Oxide of Nickel.	25. No change.	25. The same.
26. Bismuth.		26. Flies off in fumes, and leaves a mark with red or orange edges, which may be dissipated in R. F. without giving colour to the flame.
a. Oxide of Bismuth.	*a.* P. F. fuses readily, mass dark brown, yellowish on cooling. In very intense heat reduces and perforates the foil.	*a.* Instantly reduced.

ASSAY.	HEATED ALONE ON	
	PLATINUM.	CHARCOAL.
27. Oxides of Tin.	27. Protoxide takes fire, and burns like tinder into peroxide.	27. R. F. Peroxide does not fuse, but reduces in a strong prolonged heat.
28. Oxide of Lead.	28. Minium becomes black while hot; at incipient redness changes to yellow oxide, fusible into orange coloured glass.	28. Orange glass reduces into a globule of lead.
29. Oxide of Copper.		29. O. F. black globule; flows over the charcoal; under surface reduces. R. F. reduces; with strong heat gives a bead of metal.
30. Oxide of Silver.	30. Instantly reduced.	30. Instantly reduced.

ASSAY.	HEATED WITH FLUXES.		
	SODA.	BORAX.	SALT OF PHOSPHO.
1. Alkalies. 2. Baryta. a. Hydrate. b. Carbonate.	2. a. b. { Fuse, and are absorbed by the charcoal.	2. a. b. { Fuse readily with effervescence into a clear glass, which becomes opaque by Fl.	2. a. b. { As with Borax, but foam and intumesce; end in a clear glass.
3. Strontia. a. Hydrate. b. Carbonate.	3. No action on caustic strontia. b. = parts, fuses into a clear glass, becomes milky on cooling: in strong heat, bubbles, and absorbed by the charcoal.	3. a. b. { Like Baryta.	3. a. b. { Ditto.
4. Lime. a. Carbonate.	4. a. { No sensible quantity. dissolved.	4. Clear glass; opaque by Fl. a. Fuses with effervescence; with more carbonate clear glass; crystallizes on cooling.	4. Fuses in large quantity; clear glass. a. Fuses with effervescence.
5. Magnesia.	5. No action.	5. Like Lime.	5. Fuses readily; clear glass: saturated with magnesia, opaque on cooling.
6. Alumina.	6. Swells up; forms an infusible compound.	6. Fuses slowly; permanently clear glass.	6. Permanently clear.

| Assay. | Heated with Fluxes. | | |
	Soda.	Borax.	Salt of Phospho.
7. Glucina.	7. No action.	7. Clear Glass, with a large proportion of the assay; opaque by Fl.	7. As with Borax.
8. Yttria.	8. Like Glucina.	8. Like Glucina.	8. Like Glucina.
9. Zirconia.	9. Similar to Glucina.	9. Like Glucina.	9. Like Glucina, but dissolves more difficultly.
10. Silica.	10. Fuses with brisk effervescence; clear glass.	10. Fuses very slowly; permanently clear glass.	10. Very small portion dissolves; clear glass.
11. Molybdic Acid.	11. P. W. effervesces, clear glass; becomes milky on cooling. C. fuses, absorbed and reduced.	11. P. W. clear glass in O. F. C. and in R. F. glass becomes dirty brown, but not opaque.	11. P. W. and in O. F. greenish glass while hot; colourless, cold. In R. F. becomes opaque; dull blue while hot: clear and fine green on cooling. C. same phenomena.
12. Tungstic Acid.	12. P. W. dark yellow glass; crystallizes on cooling; opaque white or yellowish. C. and R. F. reduced.	12. P. W. and O. F, clear glass; not opaque by Fl. R. F. glass becomes yellow.	12. O. F. yellowish glass. R. F. fine blue glass.
13. Oxide of Chrome.	13. P. W. and O. F. dark orange glass: opaque and yellow on cooling. R. F. opaque; glass green on cooling. C. absorbed, but not reduced.	13. C. Fuses difficultly, glass emerald-green: on P. W. and O. F. the colour flies and glass becomes brown-yellow; on cooling, assumes a faint green tinge.	13. Green glass in both flames.
14. Antimony, a. Oxide of Antimony.	a. P. W. fuses; clear colourless glass, becomes white on cooling. C. is reduced.	a. C. dissolves in large quantity; glass, yellowish, hot; almost colourless, cold. If saturated, part reduced and sublimed; strong R. F. the glass becomes opaque and greyish.	a. P. W. and O. F. glass yellowish, hot; colour, flies on cooling.
15. Oxide of Tellurium.	15. P. W. colourless glass; white on cooling. C. reduced.	15. P. W. clear colourless glass; white on cooling. C. becomes grey and opaque.	15. The same.

ASSAY.	HEATED WITH FLUXES.		
	SODA.	BORAX.	SALT OF PHOSPHO.
16. Oxide of Columbium.	16. Combines with effervescence, but not fused or reduced.	16. Colourless, clear glass; becomes opaque by Fl.	16. Fuses easily; glass, permanently clear.
17. Oxide of Titanium.	17. Fuses into a clear dark yellow glass; white or grey on cooling, and crystallizes with evolution of great heat. C. not reducible.	17. P. W. fuses easily: glass colourless; becomes milk-white by Fl. R. F. glass assumes a dark amethyst-colour but transparent. In large quantity on C. and R. F. glass, dull yellow; when cold, deep blue.	17. O. F. clear colourless glass. R. F. glass on C. glass yellowish, hot; on cooling, first red, then very fine bluish-violet.
18. Oxides of Uranium.	18. C. brown-yellow; not fused.	18. P. W. dark yellow glass; in R. F. becomes dirty green.	18. P. W. and O. F. clear yellow glass; cold, straw yellow, slightly green. C. and R. F. fine green glass.
19. Oxides of Cerium.	19. C. not fused. soda absorbed; white or grey-white protoxide remains on the surface.	19. O. F. fine red, or deep orange-yellow glass; colour flies on cooling; cold, yellowish tint. Enamel-white by Fl In R. F. loses its colour.	19. O. F. fine red glass; colourless when cold, and quite limpid.
20. Oxide of Manganese.	20. P. F. fuses, green, glass clear; cold, bluish-green. C. not reduced.	20. O. F. clear amethyst colour glass; colour flies in R. F.	20. The same, but colour not so deep. Infusion in O F. boils and gives off gas. In R. F. fuses quietly.
21. Oxide of Zinc.	21. C. not fused, but reduced, with flame; white fumes, which cover the charcoal.	21. O. F. fuses easily, clear glass becomes milky by Fl.	21. Nearly the same.
22. Oxide of Cadmium.	22. P. W. not fused. C. reduced, sublimes, and leaves a circular yellowish mark.	22. P. F. yellowish glass, colour flies on cooling; on C. glass bubbles, Cadmium reduced, sublimes and leaves yellow oxide.	22. Dissolves in large quantities, clear glass; on cooling, milk white.

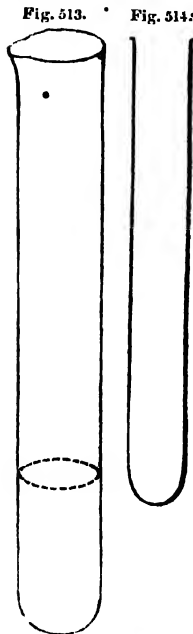| ASSAY.	HEATED WITH FLUXES.		
	SODA.	BORAX.	SALT OF PHOSPHO.
23. Oxide of Iron.	23. C. absorbed and reduced ; not fused.	23. O. F. dull red, glass becomes clear and yellowish or colourless by cooling. C. and R. F: bottle green glass or bluish-green.	23. Similar to Borax.
24. Oxide of Cobalt.	24. P. W. pale red by transmitted light; grey,cold.	24. Fuses readily, deep blue glass.	24. The same, the colour appears violet by candle light.
25. Oxide of Nickel.	25. C. absorbed and reduced ; not fused.	25. O. F. orange-yellow, or reddish glass ; becomes yellow or nearly colourless on cooling.	25. As with Borax, but the colour flies almost wholly on cooling.
26. Bismuth. a. Oxide of Bismuth.		a. O. F. colourless glass. R. F. partly reduced, muddy greyish glass.	a. O.F. yellowish-brown glass, hot; colourless, but not quite clear, cold. R. F. clear and colourless glass, hot ; opaque, & greyish black, cold.
27. Oxides of Tin.	27. P. W. effervesces, tumified infusible mass. C. readily reduced.	27. Fuses with great difficulty : permanently clear glass.	27. As with Borax.
28. Oxide of Lead.	28. P. W. clear glass becomes yellowish and opaque on cooling. C. instantly reduced.	28. P. W. clear glass, yellow, hot ; on cooling colourless. C. flows over the surface and reduces.	28. Clear colourless glass.
29. Oxide of Copper.	29. P. W. fine green glass,hot; on cooling colourless and opaque. C. absorbed and reduced.	29. O. F. fine green glass, which in R. F. becomes colourless, hot ; but cinnabar-red and opaque when solid.	29. O. F. similar to Borax. R. F. glass usually red, opaque, and like an enamel.
30. Oxide of Silver.		30. O. F. glass becomes milky, or opaline, on cooling. R. F. greyish.	30. O. F. yellowish glass viewed by transmitted light by day, by candle light reddish. R F greyish

ASSAY.	WITH OTHER RE-AGENTS.	REMARKS.
1. Alkalies.*		1. The Alkalies are not readily distinguishable by the blowpipe. *Lithia* leaves a dull yellow stain, when heated to redness on platina foil. *Ammonia* may be known by heating the assay with soda; it gives off a pungent vapour, which turns the yellow colour of moistened turmeric paper brown.

2. Baryta.
   a. Hydrate.
   b. Carbonate.
	2. N. C.; a globule of
	 a. different shades
	 b. of red; colour flies on cooling.	

3. Strontia.
   a. Hydrate.
   b. Carbonate.
	3. N. C. exhibit a
	 a. blackish colour;
	 b. do not fuse.	

4. Lime. *a. Carbonate.*	4. N. C. black or dark *a.* grey mass, infusible.	
5. Magnesia.	5. N. C.; flesh colour when quite cold.	
6. Alumina.	6. N. C.; fine blue glass, with strong heat when cold.	6. The blue colour is only distinctly seen by day light.
7. Glucina.	7. N. C.; black, or dark grey mass.	
10. Silica.	10. N. C.; blue glass when perfectly fused.	10. The part not perfectly fused with nitrate of cobalt, has a reddish-blue disagreeable colour.
11. Molybdic Acid.		11. In the inclined glass tube, fuses, gives off vapour, which condenses partly on the tube as a white powder, partly on the assay in brilliant pale yellow crystals.
12. Tungstic Acid.		12. If tungstic acid contain iron, the glass with salt of phosphorus is blood-red in R. F. Tin makes it green or blue.

* Soda and salts of soda communicate an orange tint to the flame of the blowpipe, but potassa and salts of potassa do not produce this effect.

3 G

| ASSAY.	WITH OTHER RE-AGENTS.	REMARKS.
14. Antimony		14. Antimony does not sublime at the fusing point of glass. On charcoal, when red, ignition continues spontaneously. In a tube open at both ends, it gives off white fumes.
a. *Oxide of Antimony.* b. *Antimonious Acid.* c. *Antimonic Acid.*		a. ⎰ The oxides and b. ⎱ acids of antimony c. ⎰ behave alike with the fluxes.
15. Oxide of Tellurium.		15. Metallic tellurium heated in a glass mattrass, first gives off vapour, and then a grey metallic sublimate of tellurium. In a tube open at both ends, emits abundant fumes, which condense in a white fusible powder.
17. Oxide of Titanium.	17. N. C. ; black or greyish-black.	
20. Oxide of Manganese.		20. A very minute portion of manganese gives a green glass with soda.
23. Oxide of Iron.		23. The reduction of iron from the peroxide to protoxide is facilitated by tin.
24. Oxide of Cobalt.	24. With subcarbonate of potassa, black glass when cold.	
26. Bismuth.		26. In a glass mattras does not sublime at the fusing point of glass. In an open tube scarcely gives off any fumes; the metal becomes covered with a dull brown fused oxide, of a slight yellowish tint, when cold.
31. Mercury.		31. All the compounds of mercury are volatile ; mixed with tin or iron filings, and heated in a glass tube, metallic mercury distils over.
32. Gold, 33. Platina, 34. Iridium, 35. Rhodium, 36. Palladium,		32. ⎫ These metals have 33. ⎪ no action on the 34. ⎬ fluxes, which can 35. ⎪ only serve to de- 36. ⎭ tect the foreign metals with which they may be combined. They are best examined by cupellation with lead.

*

CHAP. VI.—TUBE APPARATUS.

2948. Next to the blowpipe, there is no piece of apparatus which the student can procure that will be of so much use to him as a case of test-tubes. Although with these he cannot operate on a large quantity of materials, still there are perhaps few chemical experiments where glass vessels are required, which cannot be performed in a satisfactory manner with tube apparatus. A case of test tubes should include seven or eight of different sizes for miscellaneous operations ; a small funnel of a corresponding size ; a longer test-tube bent so that it may be used as a retort ; and several tubes with balls blown at the extremity. Figs. 513 and 514 represent the size and form of the test-tubes I find most convenient.

Test-tubes of the above size may be used for performing on a small scale all those experiments in which a glass-vessel is required, such as a flask or a precipitate glass. In general, it is better not to fill it more than one-third or one-fourth full, when it is necessary to apply heat. The test-tube may also be used as a subliming apparatus, or as a small pneumatic jar.
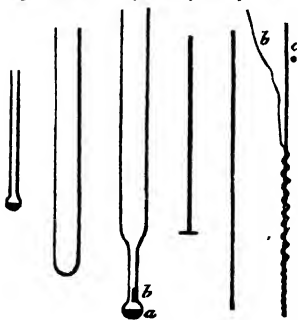
2949. Figs. 515, 516, 517, shew the smallest sizes of test-tubes generally employed when the proportion of materials is very minute, as in the reduction of excessively small quantities of arsenic. In Fig. 517, *a* represents any mixture to be heated, as oxide of arsenic and charcoal, and *b* the place where detached fragments of charcoal may

be placed which can be heated before *a,* so as to decompose any oxide that may be separated without decomposition at *a,* on the first application of the heat.

2950. Figs. 518, 519, and 520, represent a brass scraper wire, and wire with attached thread, such as are generally used in assisting the introduction of a minute charge; the thread *b* in Fig. 520 should always be held firmly by the hand, in case it should separate from *a.*

2951. When the quantity of materials to be introduced into the tube is not so minute as would be necessary in the preceding cases, they may in general be introduced most conveniently

Fig. 521.
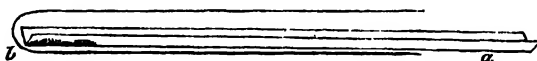
by a gutter made of glazed paper, Fig. 521, the tube being held horizontally till it reaches the extremity, after which it is placed in a perpendicular position, so that the materials may fall off without soiling the sides of the tube; the paper gutter is then withdrawn.

2952. In examining the action of heat upon any materials placed in tube apparatus, every successive appearance should be minutely attended to as it is developed, independent of the ultimate result, as the indications presented at various times often give a clue to the nature of the materials under examination. Tube apparatus, also, in cases of sublimation, should be loosely plugged with cotton, that the access of the air may not be too free, and held in the inclined position shewn in Fig.
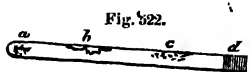
Fig. 522.

522, that all water or other fluid disengaged from *a,* may collect at *b* or *c,* without any risk of its return upon *a,* and breaking the tube.

2953. Fig. 223 illustrates the common method of heating a test-tube. A piece of paper coiled round the upper part may be substituted for the wire.

Fig. 523.

Fig. 524.

2954. Fig. 524 shews a form of tube frequently employed in experiments when a precipitate is deposited, while a liquid above may require to be heated.

2955. Fig. 525 represents a plain tube funnel for intro- _{Fig. 525.} ducing small portions of fluid into tube apparatus. It is made very easily by holding the middle of a piece of tube of the same kin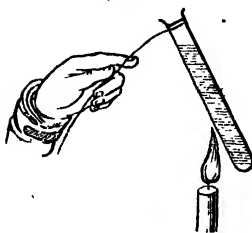d as the common test-tube (Fig. 513) in the flame of a lamp till it becomes soft, turning it continually round in the flame that the heat may be applied as equally as possible ; it is then to be removed, and the extremities are to be pulled gently away from each other. A much smaller tube is thus formed in the middle, and on dividing it, two tube funnels are procured.
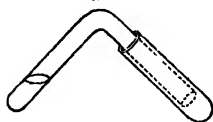
2956. Fig. 526 shews another form of the tube-funnel more generally used, for which, indeed, the former is merely to be re- Fig. 526 garded as a substitute. A short tube-funnel, with a very narrow aperture, is very convenient for pouring out small quantities of mercury ; it may be made of the form shewn in the annexed figure ; or a plain one, made in the same manner as Fig. 525, may be used.

2957. Tube-retorts and receivers are frequently employed in distilling small portions of liquid, or in preparing small quanti- Fig. 527. ties of some of the gases. The annexed figure shews one of the simplest forms of the tube-retort, a common tube, sealed at one extremity, being bent in the middle after softening it in the flame of a lamp ; a common test-tube is used as a receiver. Fig. 528 shews another form of this apparatus ; two balls blown upon a piece Fig. 528. of a test-tube are used, converting one into a retort by fixing a bent tube in it with a little lute, and introducing the extremity of the tube into the other, which is employed for a receiver. When liquids alone are put into the retort, and also in many cases where a solid and a liquid is used, a common tube-retort (Fig. 527) may be used with advantage, after blowing a ball upon the sealed extremity.
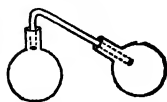
2958. Mr Kerr has proposed a particular form of tube which is very useful in experiments where a very small quantity of gas Fig. 529. is disengaged. A tube sealed at one extremity is heated in the middle only on one side, blowing into it so as to swell it out when it has become soft. It is then bent in the manner

shewn in the figure, so as to have the part that bulges out be-
low and towards the sealed end. If the sealed extremity be
filled with dilute muriatic acid, and a fragment of marble be
then thrown in, the manner in which it is used will be seen by
holding it in the position represented in the figure. None of
the carbonic acid gas escapes ; it is all collected in the sealed ex-
tremity of the tube, and may then be transferred to another ap-
paratus, filling the open end of the tube previously with water
or mercury.

2959. Fig. 530 represents a wooden case for holding test-
tubes ; it may be made about four and a half inches long, three
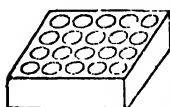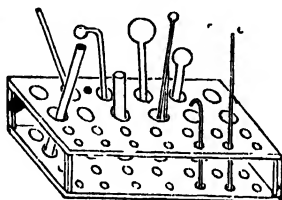
Fig. 530.   Fig. 531.

and a half inches
broad, and one inch
and a half thick. Fig.
531 shews the form of
another stand for hold-
ing glass rods, long
test-tubes, tubes with
balls, &c. It should
be about ten inches long, and six inches broad, a space of
three or four inches intervening between the upper and lower
boards of which it is made.

2960. A spirit-lamp will in general be found most convenient
for heating liquids or solids in test-tubes ; but when any mixture
is to be sublimed in a large tube, it will often be more conve-
nient to place it in a horizontal position across the top of a

Fig. 532.
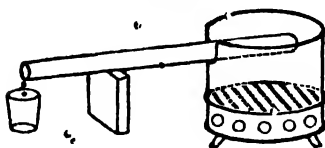
chauffer, having a piece cut out
at the side in the manner seen
in Fig. 532, coating the tube
with a mixture of sand and clay,
when it is to be exposed to a high
temperature. A chimney may
be put above it, if necessary, surrounding the coated tube com-
pletely with small pieces of charcoal.

2961. It will also be found advantageous occasionally to have
some other pieces of apparatus constructed on a smaller scale,
which may be used in connexion with the tubes themselves.
Thus, an apparatus such as is represented in the annexed figure
(533) will be found useful in operating with solutions with
which the student may exercise himself in endeavouring to de-

Fig. 533.

tect small quantities of arsenic, lead, antimony, opium, and other poisonous substances, in mixed liquids. Sulphureted hydrogen may be prepared in 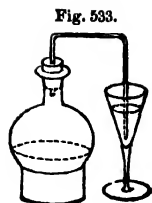it, though it should not be more than an inch or an inch and a half in diameter, and transmitted through the liquid on which he is operating in a wine-glass, as in the process for precipitating sulphurets of arsenic, lead, and antimony, or for decomposing the meconiate of lead precipitated by a solution of the acetate from a very diluted solution of the tincture of opium, so as to separate the meconic acid.

2962. Small test-tube phials, of the annexed form and size, Fig. 534, are very convenient where there is much experimenting, as a number of drops may be forced out by the pressure of the expanded air, when they are inverted, and held in the hand. They may be made of test-tube, the end being prolonged, and bent in the manner represented at the blowpipe. The acid, or other test to be used, is introduced by dipping the extremity into it, after expelling part of the air by a moderate heat.

Fig. 534.

2963. To make a common test-tube, the flame of the blowpipe must be directed upon a proper piece of tube, at the distance of four or five inches from one of its extremities, turning it constantly round that it may be exposed equally on all sides to the action of the heat, and drawing the one portion away from the other slowly ; by directing the flame upon the closed end of the tube, and heating it till it is soft, it may be made smooth and uniform in its appearance on blowing into it.

2964. The student of chemistry should study practically, with much care, the method of making the common test-tube, after examining minutely the next fifteen figures.

m shews the blowpipe lamp, with the nozzle introduced.

n, the pointed flame produced, when the stream of air is directed through the flame.

x and *x x*, a ground-plan and a perpendicular section, shewing the position of the tube when the flame is first impelled upon it.

The tube being softened, and *x x* being separated from each
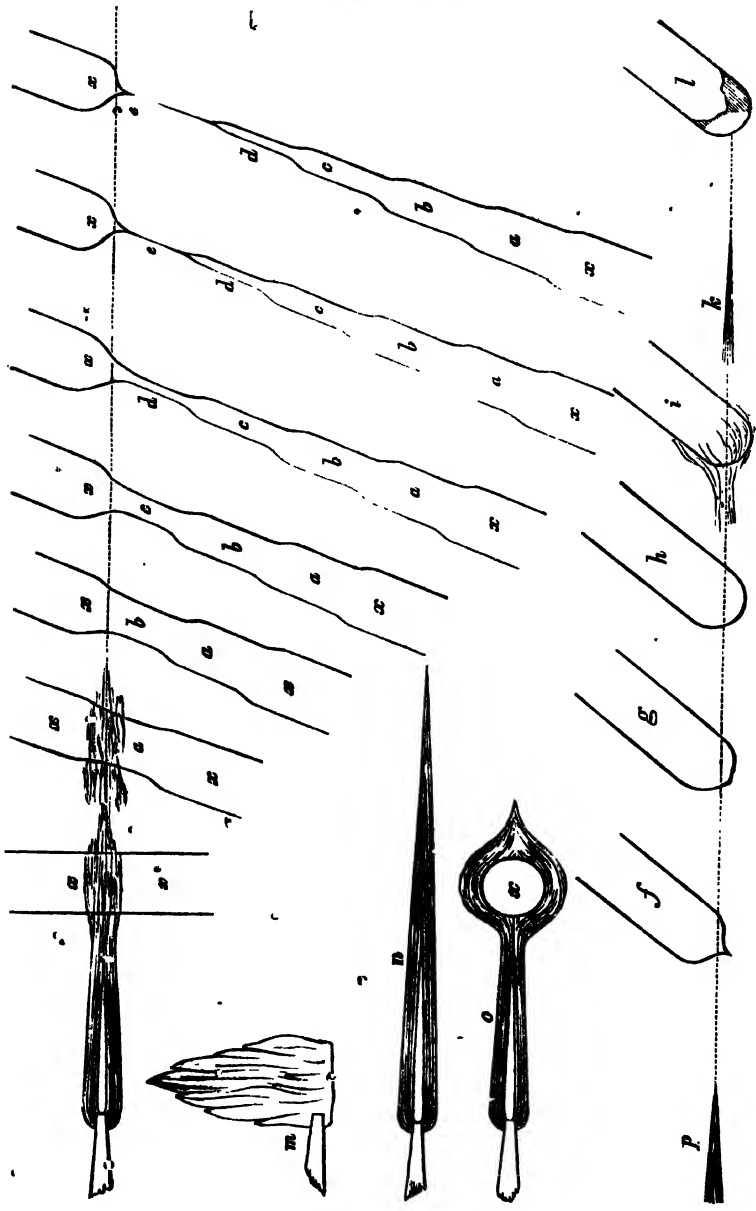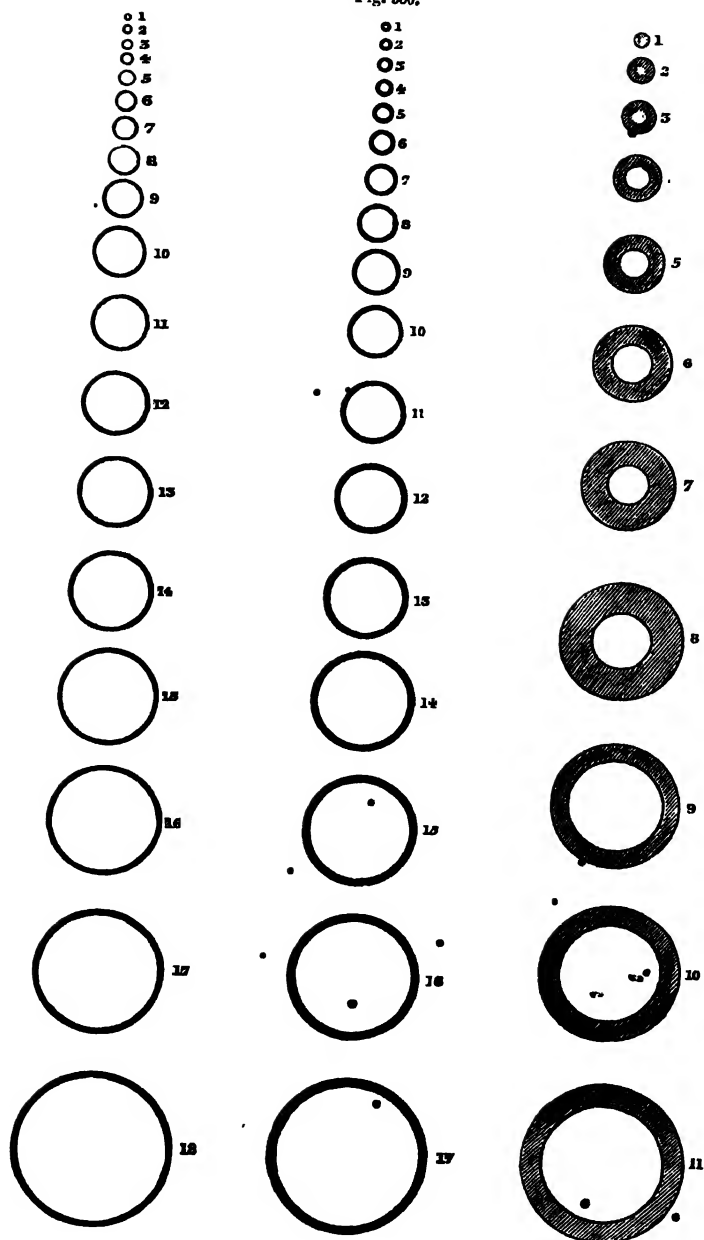
TUBE APPARATUS.

Figs. 535 to 549.

Fig. 550.

other by drawing it out a little when it is heated, it should then be inclined at an angle towards the blowpipe flame, as in the six successive figures, the great object being to exhaust or draw out as much as possible, the glass that might otherwise aggregate at the bottom of the tube, without melting an additional quantity. When a, b, c, d, e, has been detached, then the pointed extremity should instantly be turned, as in f, g, and h, till the point melts into the substance of the glass, heating it with great care only in the oxidating hot air beyond the flame. It may then be heated more sharply in the flame, as in i, till it becomes so hot, that, on blowing into it, the extremity is equally rounded ; and, if any charcoal be deposited, it should be burned off in the hot air as in l, beyond the visible flame k.

2965. The thickness of the glass-tube used should also be particularly studied. The annexed specimens, Fig. 550, shew the principal sizes in common use. Those in the first column represent the usual diameter of thin glass-tubes, such as are best for boiling fluids. They must be cautiously handled when very small, that they may not be broken. In the middle column, the thickness indicates that the glass is stout, but not so thick as to prevent it from being employed in ordinary operations where heat is to be applied to liquids. The third column shews excessively strong glass-tubes, such as are never employed except in condensing gases, connecting apparatus, and as supports for apparatus.

2966. Common flint-glass is generally employed for tube apparatus in this country ; but hard glass, free from oxide of lead, is to be preferred wherever much heat is to be applied, as it is not so easily fused as the flint glass. Light green bottle glass drawn into tubes, is a good substitute for the white glass, free from oxide of lead, where it cannot be obtained.

2967. In finishing the mouth of a test-tube, a brass rod may be used, as in Figs. 551, 552, so as to open it gently at one point, or round the whole

Figs. 551, 552.
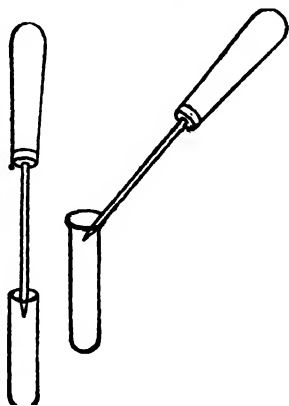
of the aperture ; or a piece of charcoal, Fig. 553,
may be turned quickly round after the mouth has
been thoroughly softened in the flame. It should
not be so soft, however, as to allow the glass to ad-
here to the charcoal.

2968. To bend glass-tubes in adjusting apparatus,
it is often sufficient to heat them in the flame of a
powerful lamp, without the use of the blowpipe ; but
when the glass is thick the blowpipe must be used.

2969. All thick glass must be heated and cooled
with great caution, otherwise it is apt to be broken
on the application of heat.

2970. To blow a ball upon a tube, seal one end, then heat
about an inch of the sealed extremity till it is soft in the rough
or smooth flame of the blowpipe. On blowing gently, it expands
into a ball.

2971. Those who are much engaged in experimenting should
recollect, that the necks of broken retorts, and broken tube ap-
paratus, may in general be rendered very useful by repairing
them at the blowpipe, so as to make smaller tubes, or by heating
them, so as to draw them out when the glass is thick, and then

Fig. 555.   Fig. 556.
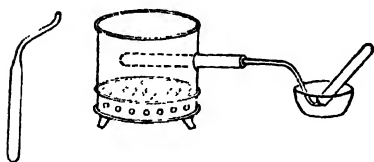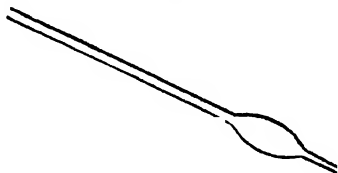
Fig. 554.

converting them into any kind of tube apparatus. Fig. 554
shews a tube with the extremity drawn to a point, such as may
be employed in collecting gaseous matter evolved from any mix-
ture on the application of heat. Fig. 555, another tube arranged
in a similar manner, by connecting it with a smaller tube. Fig.
556, a pipette made out of a retort neck. Fig. 557, a long tube,
in which different products, c and e, have been separated by dis-

Fig. 557.

tillation from *a*, any gas disengaged being evolved at *f.* These products may be separated by cutting the tube at the upper angles.

Fig. 558.	Fig. 559.	Fig. 560.	Fig. 561.
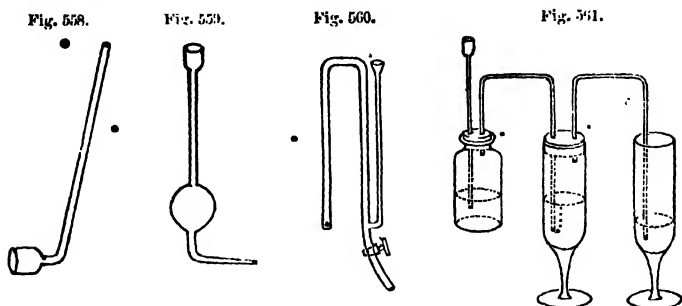
2972. In preparing pipettes, adjusting funnels and syphons, and connecting apparatus for the transmission of gases, as in Figs. 558, 559, 560, and 561, the blowpipe is continually used.

CHAP. VII.—CRYSTALLIZATION.

2973. Solids having regular symmetrical figures, dependent upon the manner in which their particles aggregate together as they pass from a fluid to a solid form, are usually termed *Crystals;* and the process by which they are produced is denominated CRYSTALLIZATION.

2974. When the particles unite with great slowness, crystals are generally large and well defined ; but, when it takes place rapidly, the crystals are usually small, confused, and indistinct.

2975. To crystallize any substance, it must previously be rendered fluid or gaseous, so that its particles may have free liberty of motion, and are allowed to return slowly to the solid form.

2976. The form of bodies may be changed by heat, or by the chemical action of any solvent.

2977. Melt bismuth in a crucible, allow it to cool till it is partly consolidated, then pour out the rest while still fluid. The crystals of bismuth extend along the sides of the crucible, presenting a very beautiful and marked appearance.

2978. Crystallize, in the same manner, separate portions of sulphur and lead.

2979. Heat, with extreme caution, a portion of benzoic acid in a flask till it is melted. Continue the heat till it is volatilized, and condenses in crystals in the upper part of the vessel. Crystallize, in the same manner, iodine, and biniodide of mercury, and aqueous oxalic acid. The common teraqueous oxalic acid may be used, two equivalents of its water of crystallization being expelled before the teraqueous acid sublimes. Great care must be taken to avoid the offensive vapours in the last operation.

2980. When a solid is rendered fluid by the action of a solvent, the latter must be removed slowly in the process of crystallization, either by permitting it to evaporate, or part of it may be expelled rapidly by heat; a stronger solution is thus procured, which will, in general, deposit crystals on cooling.

2981. When evaporation is conducted with extreme slowness in the open air, the crystals deposited are usually larger, and more regular than those separated by crystallization from a hot solution.

2982. All solutions must be saturated before they deposit crystals. A saturated cold solution affording no crystals merely on cooling, may be rendered a saturated hot solution by evaporation, which will deposit crystals as it cools.

2983. A solution, having a pellicle on the surface, is in a high state of concentration. A pellicle appears only when part of the water, or other solvent, that may have held the salt in solution has been boiled away.

2984. When saline matter is deposited rapidly from a boiling solution in numerous successive pellicles, it is said to be SALTED.

2985. In general, the stronger the solution the greater the rapidity of crystallization, and the smaller the crystals.

2286. When different crystallizable bodies meet in the same solution, should they not exchange elements they often appear in successive layers, as the solution is crystallized. Farther, after a portion of each has been deposited in crystals, the first begins to crystallize again, being succeeded in the same manner as before by the others.

2987. Wherever different layers of crystals are presented from the same solution, they are said to have been deposited by AL-

TERNATE CRYSTALLIZATION.   By taking advantage of this process, salts may often be separated.   Thus, in boiling down sea-water, sulphate of lime is first deposited.   Common salt is then separated by salting.   The drainings from the salt give crystals of sulphate of magnesia, and the drainings from the sulphate of magnesia give crystals of the muriate of magnesia.

2988. In all mixed solutions, the least soluble matter always separates first.   The salt present in largest quantity tends to separate first when their solubilities are nearly equal ; but, if one be much less soluble than the other, it may be deposited in the first instance, even though present in much smaller proportion.

2989. A salt, when contaminated with several others, may frequently be purified by solution and crystallization, rejecting the impurities which abound in the drainings.   If the crystals should not be sufficiently pure after one crystallization, they may be dissolved, and crystallized again.   Sometimes this process is repeated many successive times before the salt is obtained sufficiently pure.   Occasionally also, even after ten or twelve crystallizations, salts associated together in solution may not be entirely separated.   Dr Thomson states he has sometimes crystallized carbonate of soda a dozen of times without procuring it free from some traces of sulphate of soda, a salt with which it had been previously contaminated.

2990. The DRAININGS from the crystals of crystallized solutions are to be regarded as liquids, saturated with the salts with which they were in contact.   By concentrating them, additional crystals may be obtained, less pure, however, than the first crystals, if the salt at first shall have been impure.

2991. Hot liquids have in general a greater solving power than those that are cold.   Accordingly, hot saturated solutions usually deposit crystals when they cool.

2992. Crystals containing combined water derived from the solution which produced them, are said to have water of crystallization.

2993. Crystals may be produced without water of crystallization, which may yet contain water in small and variable proportions, in consequence of part of the fluid in which they may have been deposited being entangled and lodged mechanically between the layers of which they are composed.   A crystal abounding in

water, and fusing on the application of heat, is said to undergo the WATERY FUSION. If it then become dry, and be fused a second time, it is said to undergo the DRY FUSION.

2994. Salts that liquefy in water which they attract from the air, are said to DELIQUESCE.

2995. EFFLORESCENT SALTS are those that lose water of crystallization in a dry atmosphere, and present the appearance of flour.

2996. Crystals which split with a cracking noise on the application of heat, are said to DECREPITATE.

2997. All crystals, as Hauy pointed out, contain a PRIMITIVE FORM or NUCLEUS, which may be obtained mechanically by cleaving it in the direction in which it splits. The crystalline forms produced by the aggregation of the primitive forms, are said to be secondary or derivative.

2998. Some substances crystallize in different ways, presenting two primary forms incompatible with each other. These are said to be dimorphous from δις, twice, and μορφη, form.

2999. Bodies tend to crystallize in peculiar forms, so that these are often looked to as an indication of their purity. Form alone, however, is not a certain criterion of purity, as isomorphous bodies replace each other in different crystals without altering their figure.

3000. ISOMORPHOUS BODIES (from ίσος, equal, and μορφη, form) have the same form, and also resemble each other in many other properties. See page 615, par. 2313.

3001. PLESIOMORPHOUS BODIES (from πλησιος, near) are those whose forms resemble each other, though they are not absolutely identical.

3002. All agents which can any way affect solutions may influence much their tendency to crystallization. The form of the vessel employed, the material of which it is composed, the temperature, the state of the atmosphere, all influence the resulting product.

3003. Make a saturated solution of sulphate of soda, and pour one-half into any open vessel that it may be exposed to the air; it crystallizes in the usual manner as it cools. Place the other half in a glass flask, cork it tightly after bringing it to boil, and expelling the superincumbent air by steam; no crystallization ensues on allowing it to cool. If the cork be now withdrawn

the air enters, dissolves a portion of water, precipitates a little sulphate of soda in the solid form, and crystallization now extends rapidly through the whole mass. When the air is loaded with moisture, the crystallization is less rapid, and sometimes does not take place until a small crystal be introduced. Professor Graham has shewn that the more powerful the attraction of gases for moisture the more effectually do they promote the crystallization of such solutions when brought in contact with them.

3004. Solid substances, as a thread, a wooden spar, iron hoops, and insoluble stony substances, are often introduced into solutions to promote crystallization, or to accumulate upon them the crystals that are produced.

3005. Perform the experiment described in page 346, par. 1227, to illustrate the disposition of a metal to present a crystalline texture, even though the quantity be excessively minute. Some metallic bodies have their texture much altered by the long continued action of heat, even though they should not be rendered fluid or gaseous. The particles of some solids, when merely touched, assume a different arrangement, as the yellow biniodide of mercury, which becomes immediately of a bright scarlet colour.

FORMS OF CRYSTALS.

3006. This subject belongs more especially to the sciences of geometry and crystallography than to chemistry, though the form of crystals must always be an important subject of attention with the chemist. The reader who may desire farther information is referred more especially to the writings of Hauy, Mohs, and Weiss, the latter of whom pointed out that distinction in the systems of crystals which has laid the foundation of the more recent arrangement of crystallographic forms. The annexed figures* shew the most important forms.

3007. The cube, Fig. 562, is bounded or contained within six square planes.

3008. The regular tetrahedron, Fig. 563, is bounded by four equilateral triangular planes.

　　　　* From Brooke's Introduction to Crystallography.

3009. The REGULAR OCTOHE-DRON, Fig. 564, is bounded by eight equilateral triangular planes, and may be compared to two four-sided pyramids joined base to base. The junction of the bases is termed the base of the octohedron, and is necessarily square.

Figs. 562, 563, 564.   Figs. 565, 566, 567.

3010. The rhombic dodeca-hedron, Fig. 665, is bounded by twelve rhombic planes.

3011. Fig. 566 represents the OCTOHEDRON with a square base, bounded by eight equal *isosceles* triangular planes.

3012. Fig. 567 represents the octohedron with a rectangular base, the planes being in general unequal isosceles triangles.

3013. Fig. 568 represents the octohedron with a rhomb base; the triangular planes are scalene.

3014. The RIGHT SQUARE PRISM, Fig. 569, may be compared to the cube, after a section has been cut off parallel to any of
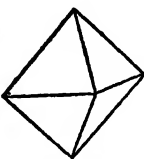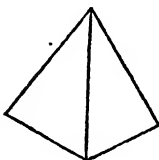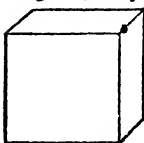
Figs. 568, 569, 570.   Figs. 571, 572, 573.   Figs. 574, 575, 576.
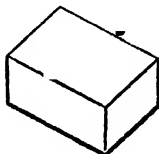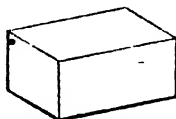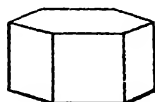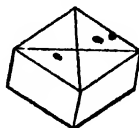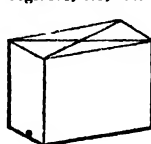
its planes.　If the newly exposed surface be placed uppermost, then it will be observed that the base is square, and that the horizontal edges are longer than those that are perpendicular.

3015.　Fig. 570 represents the RIGHT SQUARE PRISM with a *rectangular base.*

3016.　The RIGHT RHOMBIC PRISM, Fig. 571, has a rhombic base and equal lateral planes.

3017.　The RIGHT OBLIQUE ANGLED PRISM, Fig. 572, is a right prism with an oblique angled parallelogram for a base.

3018.　The OBLIQUE RHOMBIC PRISM, Fig. 573, is an oblique prism having a rhombic base, and equal oblique angled parallelograms for its lateral planes.

3019.　In DOUBLY OBLIQUE PRISMS, Fig. 574, the bases and the lateral planes are generally oblique angled parallelograms.

3020.　The RHOMBOID, Fig. 575, is bounded by six equal rhombic planes.

3021.　The REGULAR HEXAGONAL PRISM, Fig. 576, is a right prism with a hexagonal base.

3022.　In describing crystals, the plane surfaces within which they are contained are termed FACES.　The lines formed by the meeting of two places are termed EDGES, and where there are two or more edges, uniting to form a point, they produce a SOLID ANGLE.　A line joining the opposite angles of any parallelogram

Fig. 577.
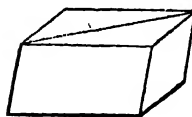
as in the upper face of the crystal, Fig. 577, is called the DIAGONAL of that plane.　The AXIS of a crystal is an imaginary line passing through a solid, and uniting in general two opposite solid angles.

CHAP. VIII.—TESTING WITH FLAT GLASS.

3023.　Practical chemists have long been familiar with the method of operating with very minute quantities in test operations, and the same mode which they have employed in their analytical investigations may also be adopted as a powerful means of enabling the student to become familiar with chemical action, as thousands of experiments may thus be performed at

the most trifling cost, and with an apparatus so simple, that it
may be said to be within the reach of every one.   All that is
required is a selection of chemicals, such as has been described
in pages 774, 775, and a number of slips of glass, which can
be procured at any glaziers.   With these the student can
boil, filter, crystallize, precipitate mixtures, and imitate some
furnace operations, with the assistance of a lamp or candle, and
the pointed glass.   In some particular cases, he may even col-
lect condensible vapours and test them, by heating a portion of
any materials that produce them, and approaching for one or two
seconds, after the slip has been removed from the heat, another
broad and cold slip as near as possible to the heated mass, with-
out actually touching it.

3024. It should be particularly remembered, in testing with
slips of flat glass, that the great object is to produce an effect
with the materials used that may be distinct and palpable, and
that small quantities are sufficient for this purpose.   A portion
of a solid, about the size of a pin's head, will generally be found
sufficient for a number of experiments.   When large quantities
are used, the heat of the lamp may not be powerful enough to
affect them, nor, in general, can the flat glass hold a sufficient
amount of water, or of other fluids, for the solution of solids, if
the quantity be considerable.

3025. The following brief illustrations of the use of flat glass
was drawn up for the use of those who wished to operate at home,
and had no time nor apparatus for experimenting in the usual
manner.   It has been copied into different works on chemistry,
and should be studied carefully by all who propose to experiment
frequently, even though they may have abundance of ordinary
apparatus, as there is no way in which preliminary test experi-
ments can be performed so rapidly as with slips of glass.

3026. SOLUTION. Broad slips of the size seen in Figs. 578 and
579, or twice the length and breadth seen there, are best adapted

Fig. 578.

Fig. 579.
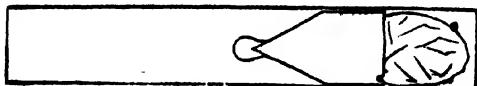
for this purpose. They are held by one extremity; and a minute quantity of the substance to be dissolved, about the size of a mustard seed, is placed at the other, which may be increased according to its solubility, covering it at first with eight or ten drops of the liquid used for solution.

3027. BOILING LIQUIDS. Slips of the same size as Fig. 578 may be employed, but they ought to be selected as thin as possible. Those which are about the twentieth of an inch in thickness do well. The part heated should be covered for the length of an inch or two with the liquid to be evaporated. The slip may be placed before the fire, in a current of warm air, or one or two inches above the flame of a very small lamp or candle.

3028. CRYSTALLIZATION. Solutions to be crystallized may be spread over the greater part of the glass, and left to evaporate spontaneously, or concentrated by heating, removing the slip from the heat the moment any solid appears on the edges. If the heat be continued longer, a confused mass is generally observed instead of crystals. Fig. 578 represents the appearance frequently seen where small needle-like crystals are produced. Glauber salts (sulphate of soda), oxalic acid, muriate of strontia, and bichloride of mercury, give solutions which crystallize with great facility.

3029. If the solution be evaporated incautiously, it soon becomes dry, and no crystals appear. It is desirable in general to evaporate, till, on cooling for a short time, traces of crystallization may be seen, as in Fig. 580.

Fig. 580.

3030. FILTRATION. When a solution is turbid, from the admixture of solid matter, it should be collected at one extremity. A small tapered piece of bibulous, or filtering paper, is then placed next it, as in Fig. 579, when the fluid in general passes along, and a drop of clear fluid is obtained at the pointed extremity of the paper. The glass slip should be gently inclined, and more water or other solvent should be added, if there be not enough to moisten

Fig. 581.
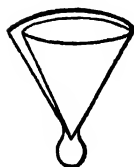
the paper. When the solution does not filter readily in this manner, a square piece of paper may be folded in two, this being again repeated, so that, on opening it in the manner seen in Fig. 581, the fluid may be poured into it as it rests on the side of the flat glass.

These slips, or the narrow slip, may also be used for PRECIPITATION. See 3031.

3031. SLIPS for TESTING, STIRRING, and LIFTING fluids. These are made of the form and size shewn in Fig. 582. Dipped

Fig. 582.

into any solution, a portion adheres to the extremity. It may then be divided into many small portions, upon a broad slip of glass or paper, by touching it with the end of the slip to which the fluid adheres. The narrow slips being cleaned in a basin of water, may then be dipped into any tests, and applied to each separate portion distributed over the glass or paper, as in Fig. 583.

Fig. 583.
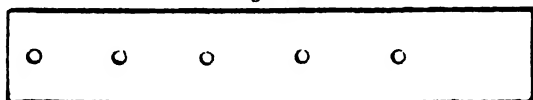
3032. A solution, from which a clear fluid is escaping during filtration, is often made to deposit successive drops upon a slip

Fig. 584.

of glass, the filter being held between the fore-finger and thumb, so that it can be brought quickly in contact with successive parts of the glass, as in Fig. 584.
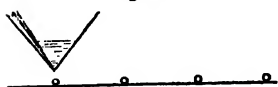
3033. For FUSION and DECOMPOSITION, the broad slips may be employed where an intense heat is not required. In examining the effect of heat where a more elevated temperature is necessary, the narrow slip should be employed, and no more taken up than can be lifted by the point, the quantity not exceeding in bulk the head of a small pin. Practise experiments of this kind with acetate of lead, red lead, sulphate of copper, sulphate of iron, nitrate of silver, terchloride of gold, and any other substances, the effect of heat upon which has already been described.

3034. In experimenting with borax and metallic oxides or other substances, heat the pointed extremity for half a minute, dip it instantly into powdered borax, a portion of which immediately adheres ; it is then brought in contact with the substance to be fused along with it, moistening it, if this be necessary, to make a little adhere. The material is usually heated in the flame of a lamp or candle. In the outer flame hot air acts upon it, but in the inner flame it is subjected to the action of hot carbon and hydrogen. Between these is the point of greatest heat.

3035. In testing metals which give coloured precipitates, paper is often used instead of flat glass.

3036. Wherever a very minute quantity of material is to be mixed with one or more tests, they should be brought to act upon it in small successive portions. The annexed figures (585 and 586) represent three drops of different liquids brought to act upon each other in this manner, the original drops, *a b c*, being gradually extended by a slip of glass till they come in contact.
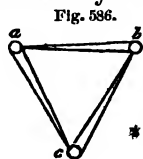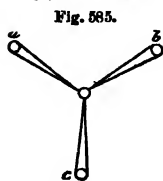
Fig. 585.   Fig. 586.

PART IV.

CHEMICAL ANALYSIS.

CHAP. I.

3037. Chemical Analysis is the investigation of the nature and properties of bodies, so as to determine their composition. It is called *Qualitative* when the object is merely to ascertain the nature of the materials in the substance examined ; and *Quantitative* when their relative weights have also to be determined. Qualitative analysis must always precede Quantitative analysis, where the component parts are not already known, as, in general, no definite line of operations can be fixed upon with a given weight of materials till its composition is ascertained. Quantitative analysis requires much more time and delicacy of manipulation than Qualitative analysis, which it necessarily includes.

3038. In Chemical analysis, all changes induced in the material examined are effected by the action of tests or re-agents, heat, electricity, light, magnetism, mechanical operations, and, in short, by all those arrangements that are resorted to for the production of chemical action, either conjointly or separately.

3039. In conducting analytical operations, the subject of experiment is usually called the ASSAY, a term which is very convenient in practice, and which we shall accordingly continue to employ.

3040. In some cases different ingredients may be separated from one and the same portion of the material examined. In others, it is desirable to divide the mass into smaller portions, one being set aside for each ingredient which may be presumed to be present, or for which it may be intended to search.

3041. In most analytical operations, some opinion is necessarily formed as to the nature of the assay from its mere appearance, which may lead at once to a specific investigation.

But where no special appearance is presented, the following preliminary investigation should be resorted to, using in each case at first a minute quantity of the assay, not exceeding in size a mustard-seed. It is scarcely necessary to remark that there are many exceptions to the general rules which follow.

3042. I. Subject the assay to heat, so as to ascertain if it be animal, vegetable, or mineral. .

a. MINERAL SUBSTANCES, excepting coal and other substances derived from it, amber and sulphur, are generally fixed and do not burn.

b. VEGETABLE MATTERS generally blacken and burn. '

c. Animal substances generally blacken and burn with an odour of bone.

3043. II. Examine it with water, hot and cold; ascertain if it be soluble by evaporating a drop of the water with which it has been heated after filtering it, should it not dissolve and disappear.

3044. III. Examine its action with the test paper both before and after heating it, mixing it with a little water, and ascertain if it be acid, alkaline, or neutral.

a. Some salts, neutral at first, may lose their base after heating, as phosphate of ammonia, from which ammonia is expelled, while phosphoric acid remains.

b. Others, as carbonate of lime, lose their acid and become alkaline. '

c. Salts of organic acids and fixed alkalis or alkaline earths become alkaline, though neutral at first, the organic acid being decomposed and generally presenting carbon.

d. Common metallic salts with vegetable acids, usually liberate a portion of the metallic base, as acetates of lead and copper, and if any fixed alkali be associated with them, as when tartrate of antimony and potassa is decomposed, it may be indicated in the usual manner by the test paper.

3045. IV. Subject the assay successively to the action of sulphuric, nitric, and muriatic acids, concentrated at first, and then diluted; let the acids also be in each case cold and then heated. Mix it also with alcohol when the acid is in excess, and burn the alcohol, observing any change of tint.

3046. V. Treat it with an alkali, using the assay both solid and in solution, if it be soluble, and with, as well as without,

heat. Try it also, if it appear like an earthy solid, with the platinum wire, Fig. 497, page 819, after mixing it with carbonate of potassa, when a bead of silicated potassa is formed. Should it consist of or abound in sand—See Silica.

3047. VI. Heat a larger portion of the assay with carbon to bright redness in a crucible. All sulphates not decomposable by heat alone, become metallic sulphates when treated in this manner; and produce, when decomposed by water, a strong sulphureous solution, which blackens lead. See page 232. On the small scale, the reduction of the sulphate may be effected in the inner flame of the blowpipe. Another mode consists in adding a small fragment of the suspected sulphate to a bead of clear and colourless silicated potassa; it becomes of a liver colour when the assay contains sulphur; the silicated potassa may be made at the moment by mixing the assay with sand and carbonate of potassa, operating with the platinum wire. See Fig. 497, paragraph 2920. The effect of charcoal upon the oxides of the common metals is most easily and quickly observed when the charcoal support is used with the blowpipe flame.

3048. Bodies not affected in any of the preceding modes are usually roasted with nitre, which communicates oxygen and potassa as it is heated.

3049. The annexed figure (587) will assist the beginner in tracing the manner in which he may practise at first in any preliminary investigation.

A (1) represents the assay which has been heated to redness, and may be afterwards tried successively with water, and test paper, acid, alkali, carbon, and nitre, as shewn by 1 to 7 inclusive.

a (8) a portion of A to be acted upon by water, and then examined, as indicated by 9 to 15 inclusive.

B (16) the assay acted on by water, but not heated previously as a was, the product to be tested in the same manner as a (17 to 22).

C (23), D (28), E (35), F (42), and 49, represent different portions of the assay to be mingled with the material at the head of the column in which they are placed, the product being subsequently tried with the others as the numbers indicate, which terminate the lines proceeding from each.

3050. Such examinations may often be much extended in

Fig. 587.

preliminary practice, by subjecting a portion of *a* for example, after being heated and tried with water, to the action of *acid*, alkali, &c. Then another portion of *a*, after being acted upon by *acid* and alkali, may be treated with carbon and nitre, and so on successively. Farther, B, C, D, E, F, and G, might also be examined in the same extended manner, as when this is considered desirable.

3051. Fig. 588 represents the result of a partial examination of a white acidulous powder, cream of tartar, a compound of tartaric acid and potassa, which will assist the beginner in entering upon examinations of this kind. From this figure he will observe that it is

I. Inflamed and blackened by heat.
Sparingly soluble in water.
Has an acid reaction on the test paper.
Presents no apparent change with muriatic acid.
Is neutralized by an alkali.
Shews the same result with carbon as with air when heated.
Deflagrates with nitre.

II. He will then notice, that, by the action of water, a black matter *a* may be separated by filtration from another substance in solution *b*, and that

III. *a* (which consists of carbon) does not affect water, test paper, muriatic acid, alkalis or carbon, but deflagrates with nitre, producing a white fused mass (carbonate of potassa) which remains unchanged by carbon and alkalis, but effervesces with acid, is alkaline in its action on the test paper, dissolved by water, and fused by heat. Lastly,

IV. *b* is soluble in water, alkaline, and effervesces with or neutralizes acids, being carbonate of potassa, similar to that formed by carbon with the nitre.

3052. Again, in making sketches, such as are represented, till he is familiar with the method of making rapidly such preliminary examinations as may be required, the beginner will find it useful to draw up short diagrams, in which he may condense those memoranda which it may be important for him to remember in each particular case. Thus, in Fig. 589, a scheme is given in which any substance has been heated, dissolved, and then portions of the solution tried successively with test-paper, acid, heat, alkali, and water; after this, another portion has

Fig. 588

I.	II.	III.	IV.	V.	VI.	VII.
Heat	Water	Water and Test-paper	Muriatic Acid	Alk.	Heated with Carbon	Heated with Nitre
Inflamed Blackened	Sparingly soluble	Acid	0	Neutral	as in I.	Deflagrates white fused mass left

A ◯

a

0

0

0

0

Alkaline

Neutr.

b

0

Deflagrates white fused mass left

0

0

0

0

Alkaline

Efferve.

0

0

Dissol.

Fuses

Fig. 40.

A ◯

B ◯

been acted upon by acid, then dissolved in water, and a portion of the solution examined by heat, test-paper, alkali, carbon, and nitre, while another part of the solid compound produced by the acid is also subjected to the action of alkali, carbon, and nitre.

3053. Sand, chalk, sulphate of iron, charcoal, nitre, carbonate of potassa, sulphuric, nitric, and muriatic acids, sulphur, acetate of lead, tartar emetic, arsenious acid, gum, and sugar, will be found to present the more important phenomena, and in sufficient variety to enable the student to see more distinctly, after some little practice with them, the mode of proceeding in preliminary investigations.

• CHAP. II.—ACIDIMETRY AND ALKALIMETRY.

3054. The method of ascertaining the exact quantity of free acid or alkali in a given weight of any solution or mixture of solid substances, is a subject of great importance, as it not only enables us to determine their value in a commercial point of view, but also to adjust the quantities of materials required for different processes and experiments. The strength, indeed, of every acid and alkaline solution used for chemical experiments should be known, and it will be found to save a great deal of time, if the solutions that are employed are always prepared of the same strength.

3055. To ascertain the strength of any acid, an operation that is now termed ACIDIMETRY, all that is necessary, is to take a given weight of an alkali, and see what quantity it can neutralize. Thus, if we wish to ascertain how much real sulphuric acid there is in a given weight of diluted sulphuric acid, we have only to take a given quantity of an alkali, or alkaline carbonate, that of potassa for example, and ascertain what weight of the acid liquid is required to neutralize it; and as it is known that 40.1 parts of sulphuric acid neutralize exactly 47.2 of potassa, we must allow 40.1 parts of acid for every 47.2 of potassa neutralized. If carbonate of potassa be employed, then every 69.32 parts neutralized indicate the presence of 40.1 of acid, containing exactly 47.2 of potassa.

3056. For example, suppose 69.32 grains of the carbonate of potassa are dissolved in water, and we find that it requires exactly 160 grains of diluted sulphuric acid to neutralize it; then these 160 grains must have contained exactly 40.1 of dry sulphuric acid, or 25.065 per cent. ; consequently, in all

experiments where a given weight of acid is required, we must take very nearly four times its weight of this diluted acid, to have the proper quantity.

3057. In the same manner, we may easily ascertain the quantity of real acid in most other strong or diluted acid liquids ; 47.2 parts of real potassa (or 69.32 of the carbonate) indicating the presence of 54.2 of nitric acid, 36.5 of muriatic, and quantities of other acids represented by their respective equivalents, when they are capable of completely neutralizing potassa.

3058. It must be obvious, that, on the same principle, we may ascertain the quantity of free alkali in any alkaline solid or liquid ; and the process for this purpose has now received the name of ALKALIMETRY.   Thus, if we should wish to ascertain the quantity of soda in a mixture of sulphate and carbonate of soda, the value of which depends principally on the quantity of carbonate of soda which it contains, we have only to dissolve it in water, and on neutralizing the liquid with a diluted acid of a given strength, we may easily calculate the quantity of free soda which it contains.   For example, if the solution of 100 grains should require 80 grains of diluted sulphuric acid, containing 25.0625 per cent. of real acid to neutralize it, then they must have contained 15.75 grains of soda ; for 80 parts of the diluted acid contain 20.05 of real acid, and 40.1 of this acid neutralize 31.5 of soda ; but if 40.1 of sulphuric acid neutralize 31.5 of soda, then half the quantity (20.05) will neutralize 15.75 of this alkali.   And farther, as 22.12 of carbonic acid are combined with 31.5 of soda in the carbonate, this quantity of soda, 15.75 parts, must have been combined with 11.06 carbonic acid.

3059. On the same principle, the quantity of potassa in pearl ash and potashes may be ascertained, and of real ammonia in the water of ammonia, substituting the respective equivalents of these substances for that of soda.

3060. For ascertaining when the neutralization is completed in these processes, nothing will be found more convenient than the blue infusion of cabbage, as a very slight excess of acid or alkali changes its colour to red or green.   Test-papers, prepared in the manner described in 545, may be used for the same purpose.

3061. A pure carbonate of potassa may be easily prepared

for these experiments, by fusing the crystallized aqueous bicarbonate in a platinum crucible. The best method of proceeding, is to pour it out on a clean iron plate after it has been kept in a state of fusion for five or ten minutes in a platinum crucible, putting a fragment of it into a small cup of water accurately equipoised in a balance, and ascertaining its weight by again counterbalancing the cup. The object of proceeding in this manner· is to prevent it gaining, any increase of weight by attracting water from the air, and both the cup and the water having been previously balanced, the additional weights required to·bring the scales again to an equilibrium represent the exact weight of the fragment put into the water.

3062. Instead of using the pure carbonate, the aqueous bicarbonate is occasionally employed for the same purpose, and as every 100.44 parts contain 47.2 of potassa (see the Table of Equivalents), we must allow 40.1 parts of sulphuric acid for every 100.44 parts of this salt which are neutralized.

3063. The common crystallized carbonate of soda is occasionally used for the same purpose, but the quantity of water of crystallization in it is said to vary, sometimes containing 10 and sometimes 11 equivalents of water, combined with one of the dry carbonate. It will be proper, therefore, when it is used, to expel all the water of crystallization which it contains by exposing it to a red heat, and use it in the form of a dry carbonate.

3064. With respect to the method of estimating the quantity of the liquid employed in ascertaining the amount of acid or free * alkali ·in any solution, there are two methods of proceeding.

3065   I. By MEASURE. For this purpose, a test-tube of the size represented, Fig. 590, containing 100 equal measures, or a vessel of the form seen in Fig. 591, but twice as high, and proportionally larger, may be used. It may be graduated to any arbitrary scale, the measures being exactly equal. Such instruments are termed ACIDIMETERS when charged with alkali for ascertaining the value of acids, and ALKALIMETERS when they are charged with acid for examining the strength of alkalis. They are usually charged with 100 measures of the

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* Free or uncombined are terms which, when applied to acids and alkalis, refer solely to such portions as are not neutralized.

liquid used, which is made of such a strength that on pouring out one, two, or more measures, one, or two, or more grains of acid or alkali shall have been used; where a very delicate examination is necessary, the test liquid is prepared so dilute that each measure shall contain only 1–10th of a grain.

3066. II. By WEIGHT. When the test liquid is to be weighed, instead of being measured, take a small glass bottle or jar of a conical form, flat at the bottom and not very tall, that it may rest steadily upon one of the pans of a balance, Fig. 592. Put into it a pipette with a very fine point, and some of the test liquid with which the strength of the alkaline solution is to be ascertained, and counterpoise this scale with weights, or shot and sand. The ball of the pipette being filled with part of the test liquid, remove it carefully, and hold it over the solution to be neutralized in such a manner that the liquid shall drop out slowly; the smallest portion can be added in this manner with facility, and on replacing the pipette after the neutralization of the liquid, the weights necessary to restore the former equilibrium indicate the quan-
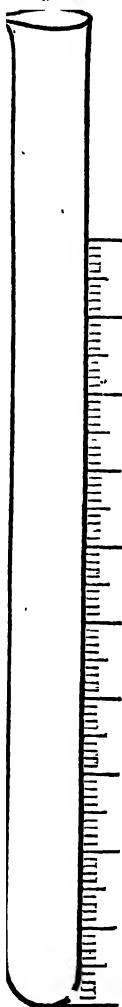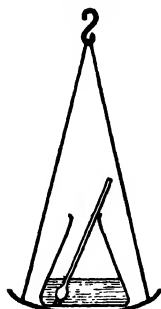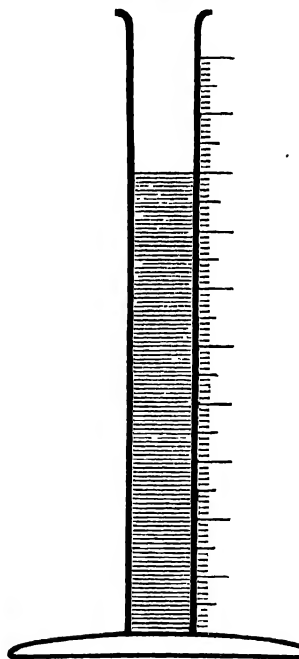
Fig. 590.

Fig. 592.

Fig. 591.

tity of liquid employed, from which the strength of the solution may be calculated as before.

Examples in Acidimetry and Alkalimetry.

3067. To prepare 400 grs. test acid containing 10 per cent. of real sulphuric acid, boiled aqueous acid must be used having specific gravity of 1.845.

Quantity of test acid required, ... 400
Quantity of real sulphuric acid required, being 10 grains
   for each 100, ... ·40
Quantity of aqueous acid containing 40 of real acid, . 48.97

From the amount of test acid required, . . 400
Subtract the aqueous acid to be used, . . 48.97
                             ————
                            351.03

The remainder 351.03 expresses the amount of water required to produce when mingled with 48.97 grs. aqueous acid, the 400 grs. of diluted test acid containing 10 per cent. of real acid.

3068. Where many experiments are to be performed, a considerable quantity, as two or three beer bottles, of test acid should be prepared at once, and reserved for experiments as it may be required.

3069. II. Required the per-centage of free potassa in 100 grs. of pearl ash, using the above acid.

1. Dissolve the soluble matter of the pearl ash in water, wash any residuum by pouring water on it, after placing it on a filter, till no more alkali is obtained, and mix all the washings.

2. Add vegetable blue which becomes green.

3. Add small successive quantities of the test acid previously balanced as described, till the alkaline solution is neutralized, recollecting that any error from a slight excess of acid is more easily checked than an error on the other side, as the eye can more readily distinguish between a blue and bluish-red, than between a blue and a bluish-green.

4. Ascertain the quantity of test acid used by examining the weights required to restore the equilibrium. Let us suppose that 200 grains were used. These contained 20 of real acid ; but 40.1 of real acid neutralize 47.2 of potassa ; and

$$40.1 : 47.2 :: 20 : 23.54$$

3 ı

23.54 grs. accordingly express the quantity of real potassa in the 100 grs. tried ; the pearl ash must therefore have been very impure, containing far less free potassa than a good specimen presents.

3070. In the same manner, the value of any solution of soda or ammonia may be ascertained, taking care to substitute the equivalent numbers of soda and ammonia for that of potassa in making the necessary calculations.

3071. III. 150 grains of the same test acid neutralized the soluble matter procured as above from 100 grs. of kelp. How much soda did they contain ?

15 grs. of real acid were contained in the 150 used ; but 40.1 of real acid neutralizes 31.5 of soda, therefore, 100 grains tried contained 11.78 grs. soda ;

$$40.1 : 31.5 :: 15 : 11.78$$

3072. IV. In estimating the value of a carbonate, the amount of alkali may in the first place be ascertained, and an equivalent proportion of carbonic acid added to it, the sum indicating the total amount of carbonate.

3073. V. When the acidimeter is used, test acid containing 1 grain in each measure may be prepared by pouring into it 122.4 grs. of aqueous acid, and then adding water till 100 measures are procured. If in any experiment with potassa 20 such measures be required for neutralization, then the same quantity is indicated as in par. 3069, viz. 23.54 grs.

3074. VI. Examine carefully the strength of a solution of potassa prepared by mixing 10 or 20 grains of fused potassa with 100 of water. Note its precise strength, and then find by experimenting with a given quantity, using the pipette, as in par. 3066, page 864, the number of grains required for neutralizing 100 grains of the sulphuric, nitric, and muriatic acids in daily use in the laboratory. These acids should be diluted with twenty times their bulk of water before the vegetable blue is added, and then the alkaline solution may be supplied by the pipette.

3075. When the common equitable blue solutions cannot be procured, test papers may be employed, taking out upon a very fine and pointed slip of glass, no more liquid than is absolutely necessary to render its action on the paper visible.

3076. When the acidimeter or alkalimeter is used, the li-

quid employed should always be at the same temperature at which it was made. In using the pipette and the balance, it is not necessary to attend to the temperature.

3077. In measuring liquids it is of great importance to attend to the line by which its weight in any measure is estimated. If we look to a tube containing mercury, it is elevated in the centre, and only one line is observed as in Fig. 593. But if we examine other fluids, as in Figs. 594 and 595, two lines are distinctly seen; the one gives a perspective view and the other a section of test-tubes with different liquids, and the lower line is preferred in such cases, as the upper line represents the surface of a minute quantity of fluid drawn up the side by capillary action.

Fig. 593.　　Figs. 594, 595.
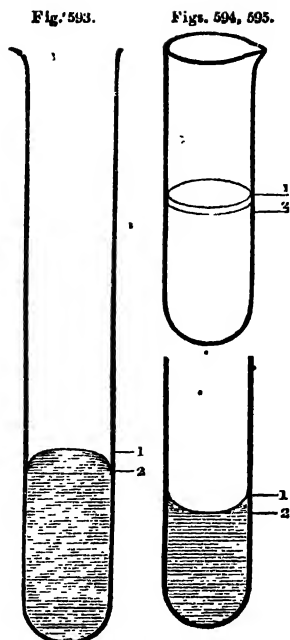
CHAP. III.—APPARATUS FOR ANALYSIS.

1. TESTS.

3079. For the greater number of analytical experiments on minerals, very simple apparatus will be found sufficient. Tubes, flasks, and evaporating basins, bottles, precipitating glasses, filters, funnels, pipettes, a·silver, a platinum, and porcelain crucible, each capable of containing from a quarter to half an ounce, small retorts and receivers, a balance, a pair of forceps, an agate mortar, and a strong spirit-lamp, constitute all that is necessary. A blowpipe and set of test-tubes are of great use, and the flat glass also may be advantageously employed in preliminary analysis.

3080. A separate apparatus is also very desirable for the preparation of sulphureted hydrogen gas, which is much employed in analytical operations. It may be made of the form represented in Figure 473, page 795.

Fig. 596.
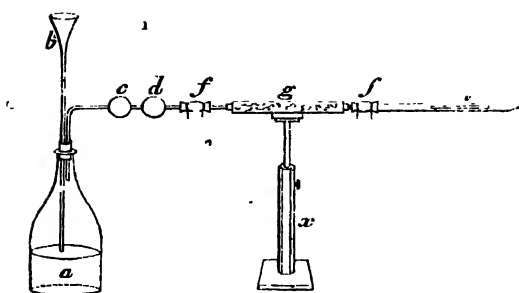
Fig. 597.
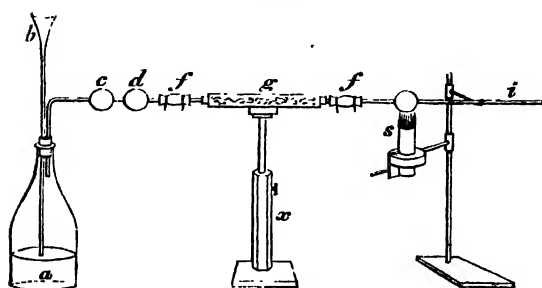
Fig. 598.
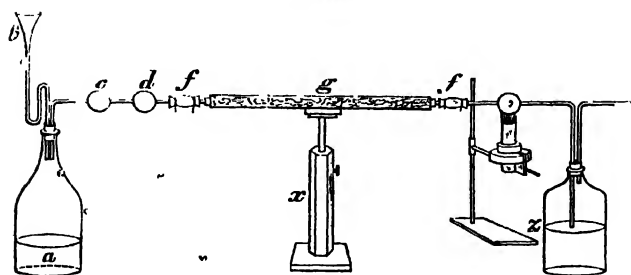
Fig. 599.
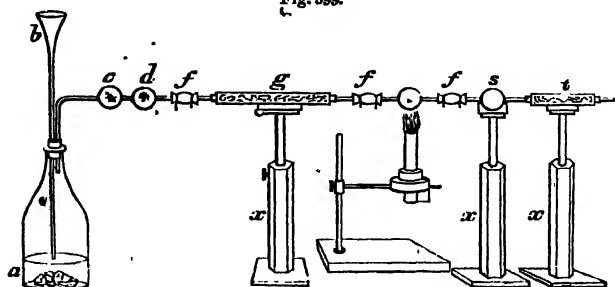
3081. The four preceding figures represent the usual disposition of apparatus employed in preparing, drying, and transmitting gaseous substances over any subject of experiment, when the apparatus requires much care and attention.

a represents bottles, flasks, or retorts for producing the gas required ; *b*, a long funnel for introducing acid in small successive quantities, or any other liquid that may be required ; *c d*, balls for intercepting any portion of fluid which may be mechanically suspended in the gas escaping from the bottle ; *g*, the tube filled with fragments of chloride of calcium for drying the gas ; *f*, caoutchouc connectors.

3082. In Fig. 596, the gas is made to act upon *i*. The assay is often placed in tubes as *g*.

3083. Fig. 597 shews the arrangement adopted when the material is introduced into a ball, and heated by a spirit-lamp *s*, as the gas passes over it.

3084. Fig. 598 illustrates the arrangement adopted when a gas produced by the action of the assay, with the gas from *a*, is to be transmitted into water, a solution of potassa, or any other substance .ained in the bottle *z*.

3085. Fig. 599 represents a still more complicated arrangement, in which the product obtained, as in the preceding figure, is subjected to still farther operations, by the materials introduced at *s* or *t*.

Fig. 600.

3086. A graduated tube is required in numerous experiments with gaseous substances, when mixed together, and detonated by the electric spark, as shewn in Fig. 359. Where the electric spark is not required, or the mercurial trough sufficiently large, the tube is often made of the form seen in Fig. 600.
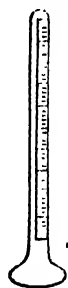
3087. In Fig. 601 a representation is given of the manner in which a platinum crucible may be heated quickly to bright redness, where air from a pipe led from a bellows or from a gasometer is made to impinge upon the flame with much force, so as to consume a large quantity of gas. The crucible is suspended

Fig. 601.

by a platinum wire from any convenient apparatus, as a retort-

stand.   Care must be taken not to direct the pipe discharging the air so as to extinguish the flame from which the gas is supplied.
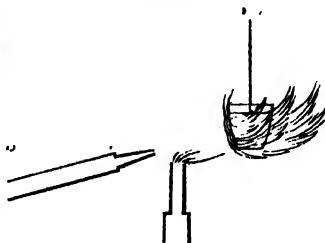
3088. As to the materials which are necessary in analytical chemistry, there are few which cannot be brought into operation in particular cases ; the following, however, are those that are generally employed, and therefore the beginner cannot too carefully test their action upon each other, so as to be certain when a complicated mixture is used, when they act upon the substance to be tested, and when, on the other hand, their indications are merely the result of their action with each other.

Distilled Water,	Benzoate of Ammonia,
Sulphuric Acid,	Succinate of Ammonia,
Nitric Acid,	Charcoal,
Muriatic Acid,	Iron,
Gallic Acid,	Copper,
Tartaric Acid,	Zinc, Tin,
Potassa,	Chlorine,
Soda,	Sulphureted Hydrogen Gas,
Ammonia,	Alcohol,
Ferroprussiate of Potassa,	Test-papers,
Nitrate of Potassa,	Sulphate of Iron,
Iodide of Potassium,	Acetate of Lead,
Borax,	Sulphate of Copper,
Phosphate of Soda,	Nitrate of Silver,
Oxalate of Ammonia,	Bichloride of Mercury,
Hydrosulphuret of Ammonia,	Bichloride of Platinum,
Muriate of Ammonia,	Bichromate of Potassa.

3089. In studying the action of all the preceding substances upon each other, they should be mixed in small successive quantities, one substance alone being mixed with another in the first instance, at natural temperatures, heat and water being applied afterwards according to circumstances.

3090. In analytical chemistry it is a good general rule to presume that no test is pure, unless it has been carefully proved to be so.

3091. Farther, all solutions that do not give any indication with the substances applied, should be examined when neutralized with much care, and also when rendered slightly acid or alkaline by any substance that does not cause a precipitate, and with various proportions of water.

CHAP. IV.

INTRODUCTORY EXAMPLES ILLUSTRATIVE OF THE CHEMICAL
ANALYSIS OF THE MORE IMPORTANT ELEMENTS AND
THEIR COMPOUNDS.

A key to these examples concludes this chapter.

3092. In the following illustrations the great object has been
to introduce the beginner to the general application of tests.
They should be studied carefully, and continual reference be
made to Part I. when any difficulty is presented, consulting the
history of the tests employed, or of the substance he may be test-
ing. The student is supposed in each case to have applied a
variety of tests, and to have selected those that appear most
important in reference to the assay ; and after having formed
an opinion upon them, he should then turn to the key and ob-
serve if he has been correct. Should it be desired to refer to
any particular subject, the student should consult the key, and
then examine the number of the subject desired.

3093. I. Solid, yellow, fusible by heat, entirely volatilized by
a higher temperature, and deposited in minute crystals resem-
bling yellow flour. Burns with a blue flame producing a pun-
gent odour, very fluid, and like amber if barely melted ; thick
and viscid before it is volatilized, and of a very deep colour.
Heat applied principally in a test tube.

3094. II. An oily looking fluid corrodes the test paper after
reddening it, dissipated with dense white and very acrid fumes
at a high temperature ; evolves heat on mixing with water ;
gives a copious white precipitate with nitrate of baryta and ace-
tate of lead insoluble in nitric acid ; sp. gr. 1.845 ; 49.1 grains
neutralize 472 of real potassa.

3095. III. A neutral solution, salts of lead and baryta give
white precipitates insoluble in nitric acid ; evaporated to dry-
ness, mixed with charcoal and exposed to a red heat in a cru-
cible, a highly sulphureous compound is procured, soluble in
water, and *blackening* lead.

3096. IV. A liquid, transparent and colourless, pungent sul-

phureous odour discharges the colour of cabbage, though a red tint may be induced in the colourless liquid by aqueous sulphuric acid, or green by an excess of alkali. Combines with alkalis, producing crystallizable salts which are decomposed with rapid effervescence by strong acids.

3097. A liquid, transparent and colourless, but depositing a sediment or becoming turbid on exposure to the air; odour, offensive and sulphureous, disappearing on exposure to air and quickly lost on boiling; reddens litmus, the colour being restored or blanched on boiling. Blackens salts of lead.

3098. VI. Solid, soluble in water, acid, not volatilized by heat, throws down from its watery solution, more especially when neutralized by an alkali, a yellow precipitate with nitrate of silver, and a white with acetate of lead ; both precipitates being soluble in nitric acid.

3099. VII. Black, with considerable lustre, solid, not consumed with facility by heat and air, disappears with deflagration when reduced to powder and heated with nitre in a green glass tube, a white mass being left, highly alkaline, effervescing with acids, soluble in water, the solution precipitating lime water.

3100. VIII. Expose 100 grains of several different kinds of coal to the action of a red heat in a crucible, and to the air, till all the carbonaceous matter is consumed, weigh the residuum, and estimate, by subtracting it from the materials originally used, the amount of inflammable matter each may have contained.

3101. IX. Take 200 grains of cannel coal, termed also parrot coal ; heat it to redness in an iron bottle, collecting the gas that is disengaged at a pneumatic trough, and examine its quality from time to time, trying more particularly the flame with which it burns, and its specific gravity.

Proceed in the same manner with common coal, taking care to give it, as nearly as possible, the same degree of heat, which need not exceed a bright red.

3102. X. Try the specific gravity of the cannel coal and of the common coal. See Specific Gravity.

3103. XI. Take 200 grains of coal, exposed previously in a dry situation, and compare the quantity and quality of gas evolved by it compared with that from an equal quantity of the

same coal, taken from a situation in which it has been exposed to moisture.

3104. XII. Solid, acid, dissipated by heat, effervesces with carbonates, almost acrid taste, reddens vegetable blue, gives carbonic oxide and carbonic acid when heated in a retort with aqueous sulphuric acid, soluble in water and alcohol. When cautiously heated, produces a vapour extremely prone to crystallize as it condenses; the solution precipitates lime water.

3105. XIII. Liquid reddens litmus, the red tint disappearing on boiling, or long exposure to the air; precipitates lime water, unless added in great excess to it; produces no black tint with solutions of lead.

3106. XIV. White, crystalline, acid, fuses by heat. Mixed with alcohol, a green tint is observed on inflaming it, though no copper can be traced on testing the solution by ferroprussiate of potass or ammonia.

3107. XV. A liquid of a pungent and penetrating odour, blanches vegetable colouring matter, dissolves gold, and precipitates nitrate of silver. The precipitate darkens on exposure to light.

3108. XVI. Liquid, acid, fumes much on exposure to the air, does not dissolve gold, unless mixed with nitric acid. Nitrate of silver gives a copious curdy precipitate, darkening on exposure to light. 100 grains dissolve with effervescence 50.62 of carbonate of lime. What is the acid, and what is its strength?

3109. XVII. Liquid, acid, transparent and colourless, fuming, discharges dense ruddy fumes with iron and many other metals; with morphia, a yellow tint is produced, followed by a deep red, which ultimately terminates in yellow.

3110. XVIII. Liquid, faintly acidulous, but becomes more powerfully so on concentration; has no action on gold, but dissolves it after the addition of muriatic acid. Neutralized by potassa, a salt is procured, which crystallizes in prisms, fuses when heated, deflagrates with paper or charcoal, and leaves a residuum highly alkaline (carbonate of potassa).

3111. XIX. Solid, transparent, and colourless; crystals thin and tabular; fuse with facility when heated; effervesces at a higher temperature, evolving oxygen rapidly; deflagrates with charcoal; leaves a residuum, which is quite neutral, soluble in water, and gives a copious curdy precipitate with nitrate of silver. Mixed in minute quantity with muriatic or sulphuric acid

in a very strong test-tube, gas is evolved, which instantly inflames oil of turpentine, and generally with explosive violence, when the last acid is employed, contains potassa.

3112. XX. Liquid, acid, coloured deeply by adding sulphuric acid or chlorine, has no action on starch, but renders it blue when either the acid or the chlorine are added. Precipitated yellow by a solution of lead, scarlet by bichloride of mercury, greenish-yellow by nitrate of silver, and of a deep port wine colour by bichloride of platinum.

3113. XXI. Solid, neutral, soluble in water, chlorine gas introduced into the solution gives a yellow colour to the solution, and on distilling it a ruddy vapour is discharged, condensing into drops of a similar tint, so deep, however, that they appear black by reflected light. These dissolve in water, and render starch yellow.

3114. XXII. Liquid, highly acid and fuming, corrodes every kind of glass and earthen vessels; heated in a leaden vessel with sand or glass, the silica is dissolved and a gas procured, from which the silica is again deposited on bringing the gas in contact with water.

3115. XXIII. Solid, white, or colourless, insoluble in water, neutral, infusible by heat, but rendered soluble and alkaline by this agent, becoming highly luminous in the flame of the blow-pipe. The alkaline solution gives little or no precipitate with sulphuric acid, the sulphate being soluble, though sparingly. Soluble with effervescence in muriatic acid, the solution crystallizing with difficulty, on the small scale, and only when highly concentrated. Burning alcohol presents a dull reddish tint when muriatic acid is mixed with it, and oxalate of ammonia gives a copious precipitate.

3116. XXIV. Presents nearly the same phenomena as XXIII. but differs from it in the following respects.

1. Dissolves more slowly in muriatic acid.

2. The muriatic solution after being completed and carefully neutralized, gives a precipitate when poured into lime-water.

3. a. Precipitate by carbonate of ammonia added in excess to the muriatic solution, so as to render it highly alkaline.

   b. Filter the liquid acid.

c. Add phosphate of soda, a copious additional precipitate is now procured.

3117. **XXV.** Solid, white, neutral, effervesces rapidly with acids, loses carbonic acid and becomes alkaline at a red heat; but the alkaline indications are excessively feeble, unless a portion of the solid be freely mingled with the coloured solution: Abundantly soluble in diluted sulphuric acid, the solution being precipitated by lime-water.

3118. **XXVI.** Solid, white, deliquescent, highly alkaline, very soluble in water, effervesces with acids, the concentrated solution gives a copious precipitate with tartaric acid. The solid has little action with the blowpipe flame, though, under particular circumstances, a violet tint may be developed.

3119. **XXVII.** Solid, white, decrepitates by heat, not affected by sulphuric, nitric, or muriatic acids. Heated to redness with charcoal for a considerable time, it acquires a sulphureous odour, dissolves readily in water, produces a solution which has a still stronger sulphureous odour, and blackens lead. The solution also gives a white precipitate with alkaline carbonates, and a white precipitate with sulphuric acid and sulphates, which is insoluble in nitric or muriatic acid.

3120. **XXVIII.** Solid, transparent, in cubical crystals, not affected by any ordinary reagent, except sulphuric acid, which produces rapidly when heated with it, after reducing it to powder, very dense and acrid fumes. If the mixture be made on a slip of glass, the glass is observed to be corroded after washing and drying it. The residuum, after expulsion of the fumes and heating it to redness, is found to be soluble in a large quantity of water, and the solution gives a copious precipitate with oxalate of ammonia, and also with nitrate of baryta.

3121. **XXIX.** Solid, transparent, and colourless, undergoes the watery fusion, and then the dry fusion by heat, efflorescent at natural temperatures, effervesces rapidly with sulphuric and other strong acids, carbonic acid being evolved. Soluble in water; the solution is highly alkaline, and gives no precipitate with tartaric acid. In the blowpipe flame, a very marked yellowish-orange tint is produced

3122. **XXX.** Solid, volatilized by heat. Mixed with *potassa, soda, or lime, and gently heated, an alkaline gas, is evolved,* which may be condensed in water ; solutions of copper give a

fine blue with this liquid. The solid is soluble in water, and the solution affords a copious precipitate with the nitrate of silver.

3123. XXXI. Solid, white, unaltered by heat, neutral and insoluble in water, not affected by charcoal at a red heat, soluble in nitric and muriatic acid. Reduced to powder and mixed with sulphuric acid, so as to form a thick paste, much heat is produced, and after digesting for a few hours, adding water from time to time and repeatedly stirring the mixture or grinding it in a mortar, it may be put on a filter, washing it till the water that passes through is no longer acid.

3124. Take one part of the solution thus procured, (A), neutralize it with carbonate of soda, filter and test it, one portion with nitrate of silver and another with acetate of lead; the silver gives a yellow and the lead a white precipitate.

3125. Take another part of the solution (B), evaporate it till it becomes of a syrupy consistence, mix it intimately with charcoal, heat it to dryness, place a small portion of it, about the size of two or three large peas, in a very infusible glass tube coated with clay, and give it a red heat, the tube being so long as to allow of the open extremity projecting beyond the mouth of the furnace or chauffer in which it is heated. Examine particularly the appearances presented as it is heated, and any deposit that may be formed near the mouth of the tube.

3126. Again, take a small portion of the solid remaining on the filter, boil it in water, and test the solution with oxalate of ammonia, and also with nitrate of baryta.

3127. XXXII. Take one hundred grains of any limestone, or of a soil known to contain carbonate of lime, neither containing, however, any other carbonate, and place

Fig. 602.

them as at *aa*, Fig. 602, on one of the pans of a balance, a solution glass, flask, or phial, *b*, being placed in the centre, after putting into it abundance of muriatic acid to dissolve all the hundred grains, should they consist of a pure carbonate of lime. The acid should be diluted with an equal bulk of water, and the mouth of the phial obstructed with a little cotton. Having balanced the whole by placing any thing, as shot and sand in the other pan, introduce the
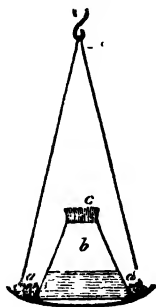
assay in small successive quantities into the acid, replacing the cotton that there may be no loss from any•little particles spirted up during the effervescence. Remove the acid from the balance till the whole shall have been introduced, then blow into it with, a pair of bellows that any carbonic acid floating above the liquid may be expelled, and restore it to the balance. The carbonic acid having been expelled, weights must be added to restore the equilibrium, and these express the amount of carbonic acid discharged. Estimate from this the amount of pure carbonate of lime in the hundred grains of limestone, marl, or soil, employed in this experiment.

3128. XXXIII. Solid, white, neutral, insoluble in water, or with a slight tinge of green or brown, unaltered by a red heat. Heated to bright whiteness in a crucible, after surrounding it with charcoal to protect it from the sides of the crucible (or on charcoal at the blowpipe, when it becomes intensely luminous), it becomes soluble in water, the solution is highly alkaline, gives a copious precipitate with sulphuric acid, and if the hot aqueous solution be concentrated, crystals are deposited on cooling. Without being heated, the solid dissolves with rapid effervescence in dilute muriatic acid, and the solution crystallizes with extreme facility, even though a very minute quantity be prepared on a slip of glass, the crystals present the general appearance represented in Fig. 578, page 851. If alcohol be poured on the muriate and inflamed, it burns with a deep crimson colour; or if a small portion be rubbed on the wick of a burning candle, it communicates the same tint, which may be renewed after it disappears by adding a little water.

3129. XXXIV. White, insipid and inert, tasteless, not' altered by heat, insoluble in water, soluble in acids, precipitated by alkalis and alkaline carbonates. Dissolved after precipitation by an excess of potassa, not soluble in an excess of ammonia. When boiled with sulphuric acid and potassa, a solution is formed which crystallizes with extreme facility, and gives octohedral crystals.

3130. XXXV. Sparingly soluble in water, the solution gives an insoluble precipitate with nitrate of baryta, insoluble in excess of nitric or muriatic acid. Oxalate of ammonia also gives a white precipitate. By carbon, heating the mixture to redness, a solid is obtained, sulphureous, soluble in water and alkaline.

3131. XXXVI. Solid, hard and gritty, or granular. Insoluble in sulphuric, nitric, or muriatic acids, affected by none except the fluoric. Fused with carbonate of potassa, an effervescence appears, carbonic acid is discharged, and a bead of glass is obtained, soluble in water if much alkali shall have been employed to assist the fusion. The solution thus obtained affords a precipitate on the addition of acids, but still more effectually on adding muriate of ammonia ; should the acid solutions not produce any permanent precipitate, on evaporating to dryness, a solid will be procured, hard and gritty, insoluble in water, and from it any substance still mingled with it, may be separated by the action of water, or muriatic acid.

3132. XXXVII. Solid, white, insoluble in water. Diluted muriatic acid dissolves one-half with effervescence, and the rest is acted upon by the agents used in XXXVI, exactly in the same manner. The muriatic solution is precipitated copiously by oxalate of ammonia, carbonates of soda, potassa, and ammonia ; sulphates and sulphuric acid do not precipitate the muriatic solution, unless it be concentrated ; lime-water and ammonia do not affect the solution.

3133. XXXVIII. Not affected by heats or acids, neutral, insoluble, tasteless, charcoal and nitre present little or no action. Fused with the carbonate of potassa in a platinum crucible, it is rendered soluble in acids, and on digesting the residuum in muriatic acid, a solution is obtained which contains also the potassa employed. If it be now evaporated to dryness and heated to redness, one of the ingredients rendered insoluble and left, while the other substance is dissolved ; on examining the solution, it will be found that a substance resembling an earth is precipitated and redissolved by an excess of alkali, and it may be entirely precipitated by using the acid in such quantity that the alkali shall be barely neutralized.

3134. XXXIX. Digest in diluted muriatic acid. A solution is procured, and an insoluble residuum which presents the same characters as XXXVI. Ammonia added to the muriatic solution precipitates an earthy looking substance, which is affected by tests in the same manner as XXXIV, and the solution that remains is similar to the muriatic solutions described in XXIII.

3135. XL. Fused with bicarbonate of potassa in the platinum crucible, to disintegrate the different earthy substances as-

sociated together, as other tests do not affect it readily, it is then dissolved in muriatic acid, and evaporated to dryness and heated, to harden and render insoluble any siliceous matter that might be present. The hard dry mass being subsequently digested in diluted muriatic acid, an insoluble solid A is left. The acidulated solution being mingled with muriate of ammonia, and an additional portion of this salt being formed on neutralizing with ammonia, a precipitate B is procured by adding an excess of ammonia. The filtered solution gives an additional precipitate C with oxalate of ammonia, and, after filtering again, another precipitate D is procured on adding phosphate of soda.

3136. XLI. To estimate the amount of magnesia and lime in a pure magnesian limestone, digest in dilute muriatic acid till all soluble matters are dissolved. Add cautiously to the solution a quantity of sulphuric acid equal to the magnesian limestone employed. Evaporate with extreme caution to dryness, and heat to redness, weighing carefully the amount of mixed sulphates of magnesia and lime thus obtained, the muriatic acid having been expelled. Reduce the mixed sulphates to powder, and triturate them in a mortar with a little cold water saturated with sulphate of lime. This solution dissolves the sulphate of magnesia from the mixed sulphates, but has no action on the sulphate of lime. On placing it on a filter, allow the sulphate of magnesia to separate in solution, and add from time to time a little more of the solution of sulphate of lime, till the washings shew that all the magnesia has been removed, giving no precipitate with lime water. The filter must then be transferred to an evaporating basin, and all the solid sulphate of lime left upon it removed from the paper, by blowing upon it some of the pure sulphate of lime solution. Then drain away all the adhering solution of sulphate of lime as much as possible, heat the dry solid to redness, and ascertain its weight. Deduct this from the total weight of mixed sulphates to ascertain the weight of sulphate of magnesia; and, from the weight of the two sulphates thus procured, estimate the weight of the carbonates in the magnesian limestone employed.

3137. XLII. Dissolve in muriatic acid, acidulated with a little nitric acid, a portion of clay iron-ore, after heating it for an hour in the open fire surrounded by fuel. Should there be any insoluble residuum after two or three digestions, fuse it in the platinum crucible with three times its weight of the bicar-

bonate of potash, dissolving the product in the same acid as at first ; and should any solid remain undissolved after this and present a dark tint, fuse it with a little nitre to burn away charcoal, proceeding again with the residuum as before, and mixing all the muriatic solutions together. Let muriate of ammonia now be added to the solution, and then add caustic ammonia till all the iron is thrown down. Boil the precipitate in a solution of caustic potassa, till any alumina mixed with the precipitated oxide of iron shall have been dissolved. Digest the precipitated oxide in muriatic acid mixed with a little nitric, and precipitate all the iron again by benzoate or succinate of ammonia ; wash the precipitate on a filter with ammonia, and having removed all the vegetable acid, heat the residuum to a very dull red heat in a platinum crucible, and estimate the amount of metallic iron in the ore by the amount of the peroxide thus procured.

XLIII. Take several portions of the roasted metallic ore, and procure from 200 grains of each a button of metallic iron in the manner described under iron.

3138. XLIV. Dissolve 50 grains of a limestone containing iron, in muriatic acid mixed with a little nitric acid. Add ammonia to the solution to precipitate the iron, and estimate its weight after heating it with nitric acid to convert it into the peroxide. Precipitate the lime by oxalate of ammonia.

3139. XLV. A metallic looking ore is soluble in nitromuriatic acid, after being reduced to a fine powder and digested for some time in a strong acid mixture ; neutralize with ammonia, and add a large quantity of ammonia in excess. An ochry looking deposit, A, appears on the filter, and a deep blue-coloured solution, B, passes into the receiver. Wash the precipitate A upon the filter with diluted ammonia till the washings come away colourless, and dissolve it in diluted muriatic acid. The solution when tested, gives black with gallic acid, blue with ferroprussiate, and red with sulphocyanate of potassa." Alkalis give an ochry precipitate.

3140. Let the solution B be neutralized with sulphuric, nitric, or muriatic acid. On testing it with metallic iron, it acquires a red metallic coating. Ferroprussiate of potassa gives a nut-brown precipitate, and arsenite of potassa a grass-green precipitate.

3141. Heat another portion of the ore in a test-tube, and observe the sulphur sublimed and condensed on the side.

3142. XLVI. Metallic lustre, soluble in nitric acid, the solution precipitated by potassa added in great excess at 212°, gives a black compound A, and a transparent colourless solution B. A gives a green tint at the blowpipe flame, a red metallic globule when heated on charcoal, and a deep blue solution with ammonia. The solution B gives a white precipitate when neutralized by an acid. The precipitate is soluble in diluted acids, and also in solutions of potassa and of ammonia. Dissolved in acids, a white precipitate, with a tinge of green, is procured with ferroprussiate of potassa, and a white precipitate by sulphureted hydrogen, or hydrosulphuret of ammonia.

3143. XLVII. Deflagrates when heated on charcoal, leaving a superficial coating of a white looking metal, which fuses into a brilliant globule if highly heated. Soluble in water, and gives a black precipitate with sulphureted hydrogen, a deep brick-red with chromate of potassa, a faint greenish-yellow (or white) with iodide of potassium, and brilliant metallic crystals on adding copper in the metallic form. Ruddy vapours are evolved when it is heated sharply in a tube.

3144. XLVIII. Soluble in ether, by which it is separated from many other substances. A watery solution is precipitated yellow or scarlet by iodide of potassium, yellow by lime water, gray by muriate of the protoxide of tin, black by sulphureted-hydrogen, white by nitrate of silver. The precipitate by the muriate of tin gives a distinct metallic-looking matter when dried and heated.

3145. L. Soluble in nitro-muriatic acid, and precipitated of a purple tint by muriate of tin ; precipitated entirely (after expelling excess of acid by evaporating cautiously, and dissolving afterwards in water the residuum thus procured) by a solution of green sulphate of iron. The precipitate is brown, and resembles more a metallic oxide than a metal ; but, on closer examination, it is found to be metallic, and to require only a sufficient heat for fusion to enable it to present the metallic form. It then appears of a yellow colour.

KEY TO THE PRECEDING EXAMPLES.

I. SULPHUR. Had there been any water mixed with it, as in white sulphur, it would have appeared on the sides of the tube. Any earthy impurity would not have been volatilized.

II. AQUEOUS SULPHURIC ACID, consisting of one eq. water and one eq. acid.

III. A solution of FIXED ALKALINE SULPHATE—See Decomp. of Sulphate of Potassa by Carbon, Part I. Earthy sulphates; do not fuse when heated. Sulphates of the common metals usually lose their sulphuric acid, and never leave a sulphuret soluble in water alone.

IV. A solution of SULPHUROUS ACID in water.

V. A mineral water containing SULPHURETED HYDROGEN.

VI. PHOSPHORIC ACID. If mixed with charcoal, and heated in a tube, phosphorus would be evolved.

VII. CARBON from coke, difficult of combustion. All carbonaceous compounds may be tested in the same manner, and especially all black crusts suspected to contain carbon, and separated from products obtained from the animal, vegetable, or mineral kingdoms, by the application of heat. Any insoluble, earthy, or metallic matter, is left after the deflagration of the carbon, which produces carbonate of potassa as it deflagrates with the nitre.

VIII. The larger the quantity of earthy residuum the less valuable the coal.

IX. The quality of gas, and also the quantity disengaged from different kinds of coal, is extremely various. The cannel coal gives the best gas, but many others give a larger quantity. The higher the specific gravity of the gas evolved, providing it be not loaded with carbonic acid, the richer its illuminating power. The best gas appears when the heat is raised to redness; but, after a prolonged discharge, the gas evolved contains much less carbon, and is largely mingled with pure hydrogen.

X. The less the specific gravity of coal, the richer in general is the gas which it evolves in carbon.

XI. When coal is charged with much moisture, the gas evolved is inferior in quality to that produced with dry coal.

XII. Oxalic acid.

XIII. Carbonic acid water.

XIV. Boracic acid.

XV. Chlorine water.

XVI. Common aqueous hydrochloric acid, containing 36.5 of real acid.

XVII. Common aqueous nitric acid. It does not dissolve gold unless muriatic acid be mixed with it.

XVIII. Diluted nitric acid.

XIX. Chlorate of potassa.

XX. Solution of hydriodic acid in water.

XXI. A soluble bromide.

XXII. Hydrofluoric acid.

XXIII. Carbonate of lime.

XXIV. Magnesian limestone, consisting of carbonate of magnesia and carbonate of lime.

XXV. Carbonate of magnesia.

XXVI. Carbonate of potassa.

XXVII. Sulphate of baryta.

XXVIII. Fluoride of calcium.

XXIX. Common carbonate of soda.

XXX. Muriate of ammonia, or sal-ammonia.

XXXI. Phosphate of lime.

XXXII. When 22.12 grains of carbonic acid are lost, the 100 grains must have contained 50.62 of carbonate of lime. 22.12 being the equivalent for carbonic acid, and 28.5 the equivalent for lime. Had 11.6 grains of carbonic acid gas only been lost, then, according to the preceding proportion, 25.31 grains only of carbonate of lime could have been contained in the 100 grains examined, as

$$22.12 : 50.62 :: 11.06 : 25.31.$$

XXXIII. Carbonate of strontia.

XXXIV. Alumina.

XXXV. Sulphate of lime.

XXXVI. Silica.

XXXVII. Silica and carbonate of lime.

XXXVIII. Silica and alumina,

XXXIX. Silica, alumina, and lime.

XL. Silica, alumina, lime, and magnesia.

XLI. Each equivalent, 68.6 grains of sulphate of lime, indicate 50.62 of the carbonate; and in the same manner each

equivalent, or 60.8 of sulphate of magnesia, indicate 42.82 of the carbonate of magnesia.

XLII. The peroxide of iron is termed more specifically a terdinoxide, and 80 grains indicate 56 of metallic iron.

XLIII. 'The iron is not extracted so completely by reduction in the crucible as by the preceding process. It is desirable, however, in the examination of ores of iron, to ascertain the amount that can be obtained according to either process.

XLIV. The iron may be estimated as in XLIV. and the oxalate of lime may be heated to 100, when it retains two eqs. of water, 82.74 indicating 28.5 of lime, or 50.62 of carbonate. If the oxalate be heated to redness, it is converted entirely into carbonate of lime, carbonic oxide being evolved. If it should be desired to reduce it to carbonate, and to estimate the amount of lime in this manner, care should be taken not to heat beyond dull redness ; and it is better to moisten it with a solution of carbonate of ammonia, that it may be thoroughly charged with carbonic acid, any excess being expelled by heat.

XLV. The ore contains iron and copper combined with sulphur.

XLVI. An alloy of zinc and copper (brass).

XLVII. Nitrate of silver.

XLIX. Bichloride of mercury.

L. Gold.

3146. From these examples, it is expected that the student will find no difficulty in selecting others. with which he may proceed in the application of tests, till he shall have included all the more important elements or compounds described in Part I.

3147. In examining organic substances, or bodies containing them, or any debris abounding in carbonaceous compounds, he will recollect that by long heat in the open air, and still more quickly by nitre or chlorate of potassa, they can all be decomposed.

3148. Again, in testing diluted solutions or mineral waters, they often require to be concentrated to a great degree before the tests act with effect, but heat, on the other hand, dissipates some of the ingredients for which they are prized.

ACIDULOUS MINERAL WATERS abound in carbonic acid gas.

SULPHUROUS MINERAL WATER usually.contain sulphur in the form of sulphureted hydrogen.

SALINE MINERAL WATERS contain principally sulphates and muriates of lime, soda, and magnesia. Iodides and bromides have also been detected.

CHALYBEATE MINERAL WATERS abound in iron.

3149. Lastly, it ought to be particularly recollected that there is no agent employed in producing chemical actions, which may not at times also be advantageously employed in chemical analysis. Electricity, in particular, appears to be an agent of this kind, and the great success of Davy, Faraday, and Becquerel amply attest its importance. Mr Roberts has lately proposed to introduce a galvanic arrangement for analyzing ores of copper, and there is every reason to believe that its practical applications will be greatly increased.

CHAP. VI.—BRIEF NOTICE OF THE ANALYSIS OF ORGANIC SUBSTANCES.

3150. The analysis of organic substances is the determination of the nature and proportions of the elements contained in the various proximate principles derived from the animal and vegetable kingdoms. Till Gay-Lussac and Thenard directed their attention to this subject, little progress was made, and their process, as modified by Berzelius, consisted essentially in converting all the carbon into carbonic acid, all the hydrogen into water, and estimating by indirect methods the amount of oxygen The nitrogen was estimated by separating it from all the other substances, and examining its volume. For these purposes, the chlorate of potassa was employed, which gave the oxygen required. The hydrogen and carbon were not estimated in a pure form, their proportions being ascertained more easily and more accurately by calculating them from the amount of water and carbonic acid which they formed. The weight of the hydrogen and carbon (and nitrogen also when it was present) having been ascertained, these are usually deducted from the total weight of

the substance employed. the remainder indicating the amount of oxygen.

3151. It is scarcely necessary to remark, that when the vegetable or animal substance contains any saline, earthy, or metallic ingredients, these must be sought for by different processes, and their respective weights ascertained apart from the examination for the four elements which have been mentioned.

3152. To prevent the action of the chlorate of potassa from being too rapid, it was mixed with common salt, but the substitution of oxide of copper was soon found to be a great improvement, and it and the chromate of lead may now be said to have superseded the use of the chlorate.

3153. One of the first objects that requires attention, is the preparation of the substance to be analyzed in the highest degree of purity, and free from water. Organic bodies absorb moisture rapidly from the air. The mode of obtaining them will depend greatly upon their source, the various properties they may present, and the materials with which they may be associated. As to the removal of the water, that is usually effected by placing the assay in any convenient apparatus, and subjecting it to the action of a stream of warm air, till the moisture is taken up, the air being heated in a sand-bath or water-bath, in which it may be raised to any temperature, according to circumstances. The apparatus, Fig. 320, page 698, illustrates the mode of proceeding ; the assay being placed in f, and heated by sand or water, saline solutions, or mercury.

3154. If any portion of the assay, from which water shall have been removed in the above manner, be placed in a small test-tube, and heated by a spirit-lamp, as far as can be done without decomposition, moisture will be discharged, and condense upon the sides should it not have been thoroughly dried. In this case, it must be returned to f, and the heat continued for a longer period. But if it do not lose weight when heated in water, a bath capable of sustaining a more elevated temperature must be substituted for the water.

3155. When water is retained with great avidity by the assay, it is necessary to exhaust the air by a syringe, and then introduce fresh air, exhausting it from time to time. and taking care to promote the evaporation in vacuo by assisting it with a high temperature.

3156. The minute details requiring attention in organic analysis are rather complicated, but have now been pointed out with much precision and accuracy by Liebig, from whose writings the following brief illustrations are taken : as, however, in this elementary work, it is not proposed to enter into these details, but rather to illustrate the general principles of the process, those who may wish to study the varied details are referred to the French translations of Liebig's analysis, edited by Jourdan and Raspail, or to the English translation announced by Dr Gregory.

3157. The tube in which the materials are mingled with the oxide of copper is usually termed the COMBUSTION TUBE, and must consist of glass free from oxide of lead.   The materials being well mixed with oxide of copper, a portion of the oxide is introduced into the closed end of the tube, the mixture succeeds it, and then another portion of oxide of copper. The tube is heated at different places successively, and all the products of the action made to come in contact with chloride of calcium in a small

Fig. 603.
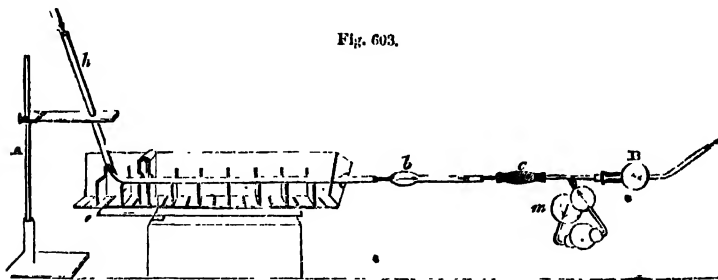
tube, and subsequently with caustic potassa.   Fig. 603 represents the general disposition of the apparatus after the heat has been withdrawn, and an addition made to each extremity of the apparatus, viz. h and B, so as to obtain a correct estimate of any watery vapour or carbonic acid gas that may have been left in the tube, for when air is sucked through B, fresh air enters the tube h, and pushes before it the moisture and carbonic acid, so that the former is condensed by the chloride of calcium in b, and the latter by the potassa in m, along with those portions discharged during the direct application of heat.   The tubes containing the chloride of calcium and the caustic potassa are weighed with extreme accuracy before they are attached.

3158. The tube employed for the conpensation of the carbonic acid by the potassa is made of the form shewn in the annexed Fig. 604, the same letters corresponding with the altitude of the liquid in the apparatus employed according to the progress of the experiment. It is usually made of wide and narrow tubes soldered together, and subsequently expanded at different places into balls so as to admit of the most perfect contact of the carbonic acid gas with the liquid employed to condense it. The general nature of the process adopted in preparing it may be traced by observing the appearance evolved in the successive tubes seen in Fig. 605, before it is bent. In Fig. 606 it is represented before the tubular portions at the extremity have been bent.

Fig. 604.

Fig. 605.

3159. To fill it with the solution of caustic potassa, one extremity is introduced into any cup *(a)* containing the potassa solution, and to the other a tube with a ball is attached, so that when the air is sucked out by Δ, the potassa enters. Fig. 607.

3160. To estimate the amount of nitrogen a variety of modes have been suggested, but it is generally directly estimated, separating it from all substances that may have been previously associated with it. Fig. 609 shews the arrangement adopted when the nitrogen is to be collected in a receiver or mercurial jar mixed with carbonic acid gas. Fig. 608 points out more particularly the varied materials that are introduced into a combus-

Fig. 606.

Fig. 607.

Figs. 608 nd 609.

tion tube where the amount of nitrogen is to be ascertained. Hydrate of lime occupies the closed extremity, and is succeeded by oxide of copper, the mixture with oxide of copper, oxide of copper again, and metallic copper, and after these the chloride of calcium in a separate tube. Hydrate of lime is used to afford moisture by which any nitrogen in the tube may be expelled and estimated in the measure. Carbonate of copper may be used for the same purpose. Part of the carbonate is heated in the first instance to expel air; and when the action of the heat upon the moisture has ceased, the rest of the carbonic acid is expelled by applying heat again to the carbonate, so that all

nitrogen left in the combustion tube may be collected.   In Fig. 609, A is the cup or cylindrical jar with mercury, B the graduated tube, *m* and *n* are perforated corks to regulate the position of B ; C, a small glass tube connected by a cork E with the combustion tube.

APPENDIX.

I.—TABLE OF EFFECTS OF HEAT AND COLD.

— 135°   Greatest artificial cold that has yet been observed.

— 121   Solid compound of alcohol and carbonic acid melts.

— 92   Greatest artificial cold, as measured by Walker.

— 55   { Greatest natural cold observed by Parry.
        Note.—Ross states it at 60 .

— 50   Cold observed at Hudson's Bay.

— 47   Sulphuric ether congeals.

— 40   Sulphuric ether boils in vacuo.

— 39   Melting point of solid mercury.

— 23   Observed on the surface of the snow at Glasgow 1780.

— 7   Brandy freezes.

+ 16   Oil of turpentine freezes.

20   Strong wine freezes.

25   Human blood freezes.

28   Vinegar freezes.

30   Milk freezes.

32   Ice melts.

36   Olive oil freezes.

50   Medium temperature of the surface of the globe.

52   Mean temperature of England.

98   Ether boils.

   98°   Heat of human blood.

  173.5 Alcohol Boils.

  212   Water boils.

  224   Saturated solution of sea salt boils.

  442   Tin melts.

  554   Phosphorus boils.

  570   Sulphur boils.

  612   Lead melts.

  650 ? (662 ? Dulong.)   Mercury boils.

  773   Zinc melts.

  800 or 810   Ignition visible in the dark.

  900 to 1100   Heat of a common fire.

1869   Brass melts.

1873   Silver melts.

1996   Copper melts.

2016   Gold melts.

2786   Iron melts.

3280   Temperature of the maximum expansion of platinum.

  ?   Heat of the oxyhydrogen blowpipe, of the galvanic
        battery, &c. &c.

II.—FRIGORIFIC MIXTURES.

TABLE I—Of Frigorific Mixtures without Ice or Snow.

Mixtures. Quantity of Materials by Weight.	Reduction of Temperature	Number of Degrees the Thermometer falls
Diluted sulphuric acid,*....4 parts. Sulphate of soda,†..... 5	From + 50 to + 3.	47
Muriatic acid,.......... .. . .5 Sulphate of soda,............8	From + 50 to 0.	50
Diluted nitric acid,‡.........4 Phosphate of soda,.........9	From + 50 to -- 12.	62
Water,. ....1 Nitrate of ammonia,..... .1	From + 50 to + 4.	46
Water, ...16 Nitrate of potassa, ...5 Muriate of ammonia,...... .5	From + 50 to + 10.	40
Diluted nitric acid,..........5 Nitrate of potassa,...........2 Muriate of ammonia,........4 Sulphate of soda,..... 6	From +50 to — 10.	60

* Composed of equal weights of strong sulphuric acid and water allowed to cool before using it.

† Crystallized sulphate of soda, which should be reduced to powder before it is used.

‡ Prepared by mixing one part of water and two of the strong acid described in paragraph 198.

TABLE II.—Frigorific Mixtures with Ice or Snow.

MIXTURES. Quantity of Materials by Weight	Reduction of Temperature.	Number of Degrees the Thermometer falls.
Snow,*..........................3 parts. Diluted sulphuric acid,.....2	From + 32 to — 23.	55
Snow,......... ....7 Diluted nitric acid,..........4	From + 32 to — 30.	62
Snow,..........................8 Muriatic acid, ...5	From + 32 to — 27.	59
Snow,†.... ....2 Chloride of sodium,.........1	From any temperature } to — 5†.	
Snow,.... . ...5 Chloride of sodium,.........2 Muriate of ammonia,.. 1	to — 12.	
Snow,........................ ...3 Crystalliz. muriate of lime 2	From + 32 to — 50	82
Snow,.....·. ....1 Crystalliz. muriate of lime 3	From — 40 to — 73.	33
Snow, ...·..8 Diluted sulphuric acid,...10	From — 68 to — 91.	23

* When snow cannot be procured, pounded ice may be substituted for it.

† I have seen the temperature of a mixture of common salt and snow fall to — 9 when a very large quantity of materials were mixed together.

III.—TABLE OF THE ELASTIC FORCE OF STEAM.

Elasticity of Steam, the Atmospheric Pressure being 1.	Temperature according to Fahrenheit	Elasticity of Steam, the Atmospheric Pressure being 1.	Temperature according to Fahrenheit.
1	212	16	398.48
2	250.52	17	403.82
3	275.18	18	408.92
4	293.72	19	413.78
5	307.5	20	418.46
6	320.36	21	422.96
7	331.70	22	427.28
8	341.78	23	431.42
9	350.78	24	435.56
10	358.88	25	439.34
11	366.85	30	457.16
12	374	35	572.73
13	380.66	40	486.59
14	386.94	45	491.14
15	392.06	50	516.60

IV.—CORRECTION OF THE BULK OF GASES FOR TEMPERATURE, PRESSURE, AND MOISTURE.

CORRECTION FOR TEMPERATURE.

As gases increase $\frac{1}{480}$th part of their volume at 32° of Fahr. for every degree of increase of temperature on the same scale, and decrease in the same ratio, we have the following rule for the correction of temperature.

To the difference between 32° and the temperature of the gas, add 480°, divide the number of inches in the volume of gas by this sum, the quotient gives the expansion or contraction for each degree at the observed temperature ; multiply this by the number of degrees between 60° and the temperature of the gas, to obtain the whole expansion or contraction, and subtract the product from the volume of the gas, if the observed temperature be above 60°, and add it if below 60°.

Example.—Correct 100 cubic inches of dry atmospheric air at 70° to the mean temperature at 60°.

$$70° — 32° = 38, \text{ and } 38 + 480 = 518.$$

$$\text{But } \frac{100}{518} = 0.19305 \text{ cubic inch,}$$

equal to expansion for one degree.

Then $0.18305 \times (70° — 60°) = 1.9305$ cubic inches, equal to whole expansion; and because the temperature is above 60°; subtract, therefore,

$$1.9305 \text{ from } 100 = 98.0695,$$

and the remainder is the number of cubic inches of air at 70° when corrected to 60°.

Again—Correct 100 cubic inches of gas at 40° to mean temperature of 60°.

$$40 — 32 = 8, \quad 480 + 8 = 488$$

$$\text{and } \frac{100}{488} = 0.20401. \text{ cubic inches,}$$

the amount of expansion for each degree at 40°.

Then $0.20491 \times (60° — 40) = 4.0982$ cubic inches, equal to expansion for 20 degrees, the difference between 60° and 40°. And because it is below the mean temperature, therefore it is to be added, and $100 + 4.0982 = 104.0982$ cubic inches, the amount of volume reduced to 60°.

CORRECTION FOR PRESSURE.

Gases obtained during any state of the barometer are under the same pressure as the surrounding air; and at any particular pressure their densities are inversely as the height of the mercury in the barometer.

Hence the following rule :—

As the standard pressure 30°,

Is to the height indicated by the barometer when the gas is obtained :

So is the volume of gas obtained,

To the volume at 30 inches.

Formula,

    Let S = Standard pressure 30 inches.

    ... h = height of barometer when gas is obtained.

    ... v = volume of gas obtained.

    ... V = volume at 30 inches.

    Then S : h :: v : V.

Example.—Suppose 100 cubic inches of gas obtained when the barometer indicated 29 inches.

    Then 30 : 29 :: 100 : 96.66 = volume at 30 inches.

CORRECTION FOR AQUEOUS VAPOUR.

Look in the following table for the amount of moisture at the temperature given, multiply the number found by the inches in the volume of gas. Correct this product for mean temperature. Subtract this correction from the whole volume corrected for mean temperature and pressure by the former rules, the remainder is the number of cubic inches of dry gas at mean temperature and pressure.

Further, multiply 0.1929 (the ascertained weight in grains of permanent aqueous vapour in a cubic inch at a mean temperature and pressure) by the amount of aqueous vapour, and this product, subtracted from the weight of the moist gas, gives the weight of dry gas.

TABLE from Faraday, founded upon the experiments of Dr Dalton and Dr Ure, shewing the Proportions by Volume of Aqueous Vapour existing in any Gas standing over, or in contact with, water, at the corresponding temperatures, and at a mean barometric pressure of thirty inches.

40°... .00933	51 .. .01380	61 .01923	71 .. .02653
41 ... .00973	52 ... .01426	62 .. .01980	72 .. .02710
42 . .01013	53 ... .01480	63 .. .02050	73 ... .02830
43 ... .01053	54 .01533	64 .. .02120	74 .. .02923
44 ... .01093	55 .. .01586	67 .. .02190	75 .03020
45 ... .01133	56 .. .01640	66 .. .02260	76 . .03120
46 ... .01173	57 ... .01693	67 .. .02330	77 .. .03220
47 .. .01213	58 . .01753	68 .. .02406	78 .. .03323
48 . .01253	59 .01810	69 .02483	79 ... .03423
49 .01293	60 .. .01866	70 .02566	80 ... .03533
50 .01333			

EXAMPLE OF CORRECTION FOR AQUEOUS VAPOUR.

Suppose we obtain 200 cubic inches of gas standing over water, weighing 400 grains. Temperature 55°, height of barometer 29 inches.

Opposite 55° in the table is found .01586, the portion of aqueous vapour in gas at that temperature in contact with water and

$$.01586 \times 200 = 3.17200$$

the amount of watery vapour in the 200 cubic inches. Correct this to mean temperature, and the result is

$$\frac{3.17200}{(55° - 32) + 480} \times 5 \ i. \ e. \ (60 - 55) = .03153,$$

and $.03153 + 3.17200 = 3.20353 =$ the corrected volume of aqueous vapour.

The whole volume corrected to mean temperature becomes 201.98807,

$$\text{for } \frac{200}{(55 - 32) + 480} \times 5, \ i. \ e. \ (60 - 55) = 1.98807,$$

$$\text{and } 1.98807 + 200 = 201.98807;$$

and this corrected for pressure is 195.25513.

For   30 : 29 : : 201.98807 : 195.25513 the volume corrected for temperature and pressure.

From this subtract the amount of aqueous vapour,   3·20353

                                                         192.05160

The remainder expresses the volume of dry gas corrected for temperature, pressure and moisture.

Now, as every cubic of inch of permanent aqueous vapour weighs 0 1929 grains,

$$3.20353 \times 0.1929 = 0.61796 \text{ grains}$$

equal to the weight of moisture.

Hence 400 — 0.617796 = 399.38204 grains the weight of 192.05160 cubic inches of dry gas.

V. — EXTRACT FROM THE DESCRIPTION OF STEPHENSON'S LOCOMOTIVE ENGINE.

Mr Stephenson's Locomotive Engine is capable of evaporating seventy-eight cubic feet of water per hour, or eight gallons in a minute ; and from the large amount of this power comes its great superiority to the old locomotives, which could evaporate only about sixteen cubic feet per hour.

The consumption of fuel per mile for every ton of the gross load is about a quarter of a pound, and that of the water is rather less than a quarter of a gallon ; the consumption increasing to nearly one-half, according as the engine is less fully loaded, being proportionally greater with a light load ; the consumption of water, when working with a full load, is a cubic foot per hour for each horse power, which is also the usual proportion in stationary engines, although these condense the steam. About eight pounds of fuel are required to evaporate a cubic foot of water, being nearly the same as in stationary engines ; but in the old locomotives as much as eighteen pounds were required in consequence of their having so small a heating-surface, which was only about two and a half square feet for each foot of water evaporated per hour, the proportion in the present one being five and a half square feet, and in stationary engines as much as eight.

The great power and velocity of locomotive engines could not have been obtained without the rapid means of generating steam afforded by the use of the tubes ; and the tubes would have been useless, without the powerful draught produced by the blast, which increases in intensity with the velocity, and with the necessity for its increased action.

VI.—THE CHEMICAL ABACUS.

The chemical abacus consists merely of the common abacus, so much employed by the ancients, and still used in different

continental citiès, especially at St Petersburgh, symbols repre-
senting any elementary or compound bodies being placed along
the side as shewn in the figure.   The more important elements
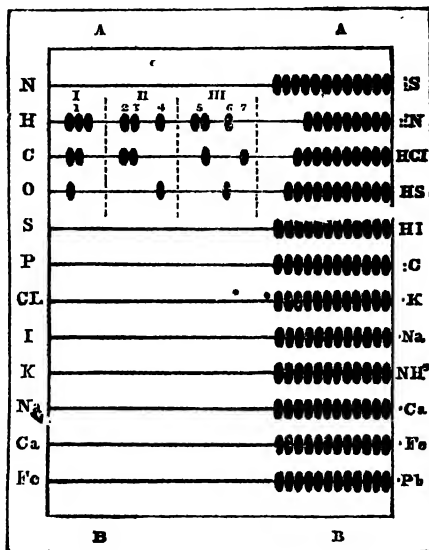
are placed on one side, and their compounds on the other, and
when the abacus is used, the beads are placed to the right when
intended to represent elements, and to the left when they repre-
sent compounds.   The figure shews it arranged in the former
manner, and six beads separated from the rest to illustrate
the composition of alcohol.   In I, they are supposed to be
united together : II represents the same beads disposed so as
to form two particles of hydruret of carbon (2 and 3), and one
of water (4) ; III shews another arrangement of the same ele-
ments, viz. bihydruret of carbon (5), water (6), and carbon (7).
The student may procure a chemical abacus for sixpence or a
shilling, or he may make one for himself by stringing a few
glass beads upon wires fixed in wood ; he should practise fre-
quently with it till he becomes familiar with the various changes
of which the most important compounds are susceptible, whether
decomposed with or without the addition of other substances.
I may be permitted to state that I was induced to suggest the
use of the abacus for the above purpose, from observing the

facility with which many calculations were made with it, in places where it is in daily use, and from the conviction that it will contribute greatly to facilitate the acquisition of a more precise knowledge of the details of the atomic theory.
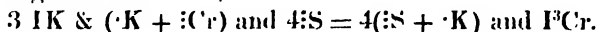
VII.—TERIODIDE OF CHROMIUM.

DISCOVERED BY MR HERBERT GIRAUD.

(*From the Philosophical Magazine,* Vol. XII. Page 322.)

" 33.5 grains of chromate of potassa were intimately mixed with 165.45 grains of dried iodide of potassium (the quantities being in the proportion of 3 equivalents of iodide of potassium to 1 of chromate of potassa); these materials were then introduced into a tubulated retort, to which a receiver was adapted; about 70 grains of fuming sulphuric acid were then poured upon the materials in the retort; this instantly gave rise to intense chemical action, accompanied by the evolution of much caloric and the production of heavy garnet coloured fumes, which constitute the iodide of chromium in a state of vapour. The elevated temperature already induced was sustained by means of a spirit-lamp, and the fumes continuing to come over were condensed in the neck of the retort and in the receiver. A small proportion of free iodine and also of sulphuric acid were carried into the receiver; the products remaining in the retort were sulphate of potassa and green sulphate of the oxide of chromium "

In every attempt which I have made to procure this substance, with varied proportions of the materials, I have never been able to obtain it quite independent of a small proportion of free iodine and sulphuric acid; it therefore appears, that it is not essential that the materials should be employed in the exact proportions of their equivalents. The essential changes which occur in the formation of this substance are expressed by the following formula :

3 IK & (·K + ͏3Cr) and 4͏3S = 4(͏3S + ·K) and I͏3Cr.

The teriodide of chromium, like the other compounds of that metal, is remarkable for the brilliancy of its colour, which is of

a deep garnet hue ; it is a fluid of an oily consistence, heavier than water, condensed into a deep vapour possessing the same colour as the fluid at a temperature of about 300° Fahrenheit. When exposed to the air, it attracts moisture, and thence gives rise to watery fumes ; by mixture with water it is resolved into chromic and hydriodic acids ; it destroys organic substances, gives a black colour to paper and wood, stains the skin of a deep and permanent brownish-red colour, and destroys the cuticle : it is also destructive of animal and vegetable life.

VIII.—SESQUI-CARBONATE OF AMMONIA.

From experiments made lately by Mr Scanlan, and researches conducted formerly by Dr Dalton, it appears that there is no sesqui-carbonate of ammonia, the common carbonate being merely a mixture of the carbonate and bicarbonate. On the addition of water, the carbonate principally is dissolved at first, and ultimately the bicarbonate, so that the saturated solution procured by the first portion of water employed may have a higher sp. gr., and be very different from that ultimately obtained. Dr Dalton says, " I took abundance of salt, that is, what is commonly called carbonate of ammonia, first poured a small quantity of water on the salt, then tried its specific gravity, which was 1.114. A second solution was 1.106, a third 1.093, and each diminishing, the last (the seventh) was 1.043, when it was all dissolved. A like sample, dissolved altogether, gave a solution having the sp. gr. 1.086."

IX.—PHOTOGENIC DRAWING.

This term has been introduced to express a mode of taking drawings, in which the delineations are affected by the action of light on paper, or other substances charged with a chemical preparation extremely sensitive to the impulse of light. Different methods have been proposed, one more particularly by Daguerre, the description of which has not hitherto appeared,

the second by Talbot, the general arrangements for which are as follow :—Take paper and steep it in a dilute solution of salt, dry it, and steep it again in a dilute solution of nitrate of silver, so as to impregnate the paper with chloride of silver. which is formed upon it by the mutual action of the common salt and nitrate of silver. By repeating this in diluted solutions with much care, excluding the light as the paper is dried, a surface is at last obtained fit for use. When a drawing is to be made with this paper. an outline, or engraving. or a leaf, a flower, or any similar object, is properly arranged on one side of a thin glass plate, and the prepared paper on the other, and on exposing the first to a brilliant light, the prepared paper is darkened wherever the light is not intercepted by the leaf, the engraving, or other object to be delineated. The lime-ball light at *a*, with

a reflector *b*, admits of this process being conducted easily with artificial light, *c* represents paper with a series of lines, *d* the interposed glass, *e* the photogenic paper, presenting, after having been acted upon, the reverse of the pattern. As the subject appears to engage very general attention at present, some more minute and practical details will very soon be laid before the public. Several substances have been recommended for preserving the drawings, more particularly the iodide of potassium, a solution of it being spread upon the paper ; they ought, however, to be excluded as much as possible from the light, and never exposed to the bright light of sunshine.

X.—MR ROBERTS' MODE OF BLASTING ROCKS BY THE AID OF GALVANISM, AND OF DETONATING GUNPOWDER UNDER WATER.

N P, N P, N P, represent the positive and negative wires from a galvanic trough, each wire being surrounded with cotton, so that electricity cannot pass from the one to the other, except by the small wire, as represented in the magnified figure with
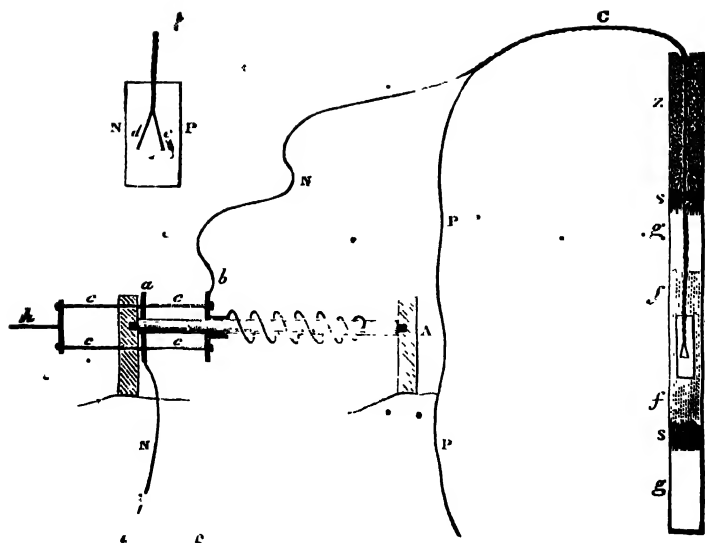
the attached arrow.   This little wire connecting the posi-
tive and negative wires, becomes incandescent when the galva-
nic trough is put in action, detonates the gunpowder in the car-
tridge in which it is contained, which inflames the additional
gunpowder *ff*, in which it is imbedded ; *s s* represents straw
used in Mr Roberts' arrangements for supporting the gun-
powder and the sand, &c. Z.   The effect of the powder is in-
creased, according to his views, by leaving atmospheric air
above and below it, as at *g*.   The galvanic trough being ar-
ranged and in action, the moment the string *h* is pulled, it
moves the light frame *c c*, and causes the metallic plate *b*, pre-
viously held back by a spring coiled upon the wooden frame
A, to touch *a* ; and the galvanic circuit being now completed,
electricity passes at once from P to N, detonating the gunpowder
as the little wire is ignited

   The metallic wires do not require to be above twenty or thirty
feet long, and the operator may retire to any distance before he
pulls the string *h* ; the effect of the blast is considerably in-
creased by there being no vent required, as in the usual mode
for igniting gunpowder.   One of Young's troughs, with twenty
pairs of plates, the plates being about four inches square, does
very well for this purpose.   It may be charged with a solution

of sulphate of copper acidulated with sulphuric or nitric acid. The metallic wire in the gunpowder, connecting the positive and negative poles of the trough, cannot be too small; it may be made of platinum, but steel wire has been preferred.

XI.—MR GLASS'S PROCESS FOR PREPARING POTASSIUM.

Mr Glass informs me, that he has succeeded in preparing potassium in larger quantity, and with much more facility, than it has been hitherto procured, by a modification of Brunner's process, the details of which he intends to lay before the Society of Arts. He uses charcoal and potassa, and a peculiar form of receiver, in which the potassium is accumulated. No naphtha is required in the receiver, at least during the preparation of the potassium.

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